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SODIUM CARBONATE SALINIZATION OF SOILS IN SOUTHERN SIN'TSZYAN (SINKIANG)

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Of the various types of present day soil salinization, sodium carbonate salinization is one of the most unfavorable. Many cultivated crops experience severe stunted growth or perish when small quantities (traces) of normal sodium carbonate appear in the plowed layer; the soils, as a rule, acquire unfavorable properties.

Melioration of sodium carbonate soils entails great difficulties. The leaching of sodium carbonate soils often does not produce satisfactory results, because the solonetzization arising with this form of soil salinization practically precludes the deep infiltration or percolation of water supplied by runoff. This water lies stagnant for a long time on the surface and only contributes to further deterioration of the quality of reclaimable lands. In order to avoid these residual effects we should carry out expensive chemical land improvements, of which gypsum treatment is the most often recommended. On the whole, other means of altering and improving sodium carbonate soils, for example, hauling in soil, improving land by silt deposition from waters, and several other methods, are characterized by great labor consumption and are not always effective enough in the presence of an active solonchak process.

If we take into consideration that sodium carbonate salinization occurs in isolated centers in a number of regions with intensive agricultural production and that the reasons for its development are not always sufficiently clear, it becomes obvious that sodium carbonate salinization deserves the careful attention of soil scientists.

Before turning to a discussion of the data obtained from our investigations, it would be expedient to dwell on several specific characteristics of the sodium carbonate salinization in soils, well known on the basis of earlier studies.

Sodium carbonate soil salinization is best known in the northern hemisphere where it appears in isolated centers in several bioclimatic zones.

In the western and, partly, central regions of the Eurasian continent, sodium carbonate salinization is attracted by the belt of chernozem and meadow steppe plains, made up of various sedimentary rocks of the quaternary period. Thus, in Europe, sodium carbonate salinization

occurs in the Pannonskaya and Vengerskaya lowlands, in the area of the Dnieper depression, in the central chernozem region of the RSFSR, in the Samara River basin, and in several other areas—chiefly in river flood plains. In western Siberia sodium carbonate salinization is well known on the Baraba lowland and on the more southern Kulundinskaya steppe.

Beginning with the Kulundinskiy center, and especially farther to the east, sodium carbonate salinization becomes associated principally with the dry steppe zone containing chestnut soils. It is associated here, as in most other places, chiefly with meadow soil formation conditions occurring within the more moisture-laden depressions of the hollow-mountain and mountain-valley relief. Here belong the comparatively rare sodium carbonate salinization centers in the Soviet Zabaykal'ye and the somewhat more frequent centers in Inner Mongolia (Chinese People's Republic). In the region of the Far Eastern prairies (as Yu. A. Liverovskiy calls them), mainly in the Chinese People's Republic and partly in the USSR, we encounter sodium carbonate salinization centers on the alluvial plains of the Ussuri and Sungari Rivers and in the region of Lake Khanko amidst unique meadow-chernozem soils.

Sodium carbonate salinization is well known on the terrace plains of Central Yakutiya in the taiga-forest zone where it develops under permafrost conditions.

In the sub-boreal deserts and semi-deserts of the northern hemisphere there are several sodium carbonate salinization regions: in the Araratskaya valley (Armenia), the Karabakhskaya steppe (Azerbaijan), the Ili and Chu River valleys (Kirgizia). Sodium carbonate salinization is associated here with meadow types of soil formation amidst sierozem, grey cinnamon-brown and several other soil groups. As this belt continues eastward we find centers of sodium carbonate salinization in the Chinese People's Republic, where until recently very little research had been done on the subject. Over the whole expanse this more southern region of episoidal sodium carbonate salinization corresponds to latitudes of 40° - 50° , and partly to lower latitudes (for example, in Iran and India), where possibly we should distinguish another belt of sodium carbonate salinization centers.

The pattern distribution of sodium carbonate

salinization in the foregoing 2 latitudinal zones differ. In the first, more northern belt, sodium carbonate salinization occurs in the midst of huge continental lowlands where it gravitates toward the mezo-depressions of the relief having a relatively close occurrence of ground waters. For this reason sodium carbonate salinization is always detected in small centers. The phenomena of local salt differentiation on one or another lowland (if other easily soluble salts are found along with sodium carbonate), are not detected as a rule. At the same time we do not observe any clear sodium carbonate concentration in any direction. These characteristics, besides the effect of climatic and geomorphological factors, should be due to the character of sodium carbonate origin. However, the reasons for sodium carbonate salinization in a large area of lowlands still are not sufficiently clear. There is reason to assume that in several places in this zone the appearance of sodium carbonate in the soils is associated with the slow movement toward the surface (from the microfissures of geological structures) of sodium carbonate solutions from mineral resources, including solutions paragenetically associated with oil deposits. Familiar, too, is the opinion expressed by several authors regarding the origin of sodium carbonate in the soils of this zone as a result of the biochemical reduction of sulfates (K.D. Glinka, N.V. Orlovskiy, A.R. Verner, I.N. Antipov-Karatayev), while according to another idea (V.A. Kovda), sodium carbonate originates as the result of the hydrolysis, in the presence of CO_2 , of sodium silicate formed during the weathering of rocks.

In the second, more southern belt, sodium carbonate salinization also has an "isolated seat" character but is associated with other geomorphological and geological conditions. Here sodium carbonate salinization appears whenever there are necessary prerequisites for the development of general salinization near the earth's surface. In particular, sodium carbonate salinization is most often observed on the alluvial fans of mountain rivers, on piedmont plains, and in valleys between mountains. On all these surfaces sodium carbonate salinization appears amidst a spatial differentiation of salts, characterizing one of the first stages of present-day salt accumulation. The development of sodium carbonate salinization should be regarded here as an element of the zonal-geochemical processes. The presence of large granite masses among massive crystalline rocks forming the adjacent mountain structures¹ is a necessary factor for sodium carbonate formation under these conditions.

The patterns of sodium carbonate salinization development in dry regions have been studied mostly on the alluvial fans of mountain rivers. We know that in the alluvial fans a large amount of river water is lost by filtration into the lower depths of soil. This water is subsequently dispersed throughout the fan and dissipated primarily by evaporation through

the soil and by transpiration. The compounds dissolved in it are gradually accumulated in the remaining portions of the solution and in the soils. Spatial differentiation of salts as a result of differences in their solubility occurs in the movement of geochemical flow. For this reason there emerge soil salinization zones which replace one another.

In the absence of sodium carbonate the solutions saturate earlier and nearer the apex of the fan, and calcium and magnesium carbonates followed by calcium sulfates form the first salt zone. Later and downward through the local gradient alkaline sulfates are accumulated and, finally, in the peripheral areas of the fans there is an accumulation principally of chloride salts (S.I. Tyuremnov, N.A. Dimo, B.B. Polynov, L.V. Pustovalov, V.A. Kovda, and others).

In the presence of sodium carbonate this sequence is somewhat disrupted. The accumulation of sodium carbonate in the soils begins always from the very weak concentrated solutions, when other readily soluble salts are accumulated very little in the soils (for example, sodium sulfates, which sodium carbonate resembles by solubility). A deposit of gypsum, both above and somewhat below the zone of sodium carbonate salinization, does not result, because gypsum and sodium carbonate are mutually eliminated as the result of the chemical reaction of the exchange. The deposit sequence for other easily soluble salts below the region of sodium carbonate salinization remains natural with the following exception. Following the zone of sodium sulfate accumulation in the soils a small quantity of gypsum appears occasionally. Its origin is not entirely clear, since in the initial solutions containing sodium carbonates, gypsum should be missing.

In accordance with what has been said, the sodium carbonate on the alluvial fans will form most often the first, and, as a rule, a somewhat isolated zone of dangerous salinization. Sodium carbonate usually does not penetrate down through the slope, especially in a region of chloride salinization, whereas the other salts, besides forming individual zones or belts, continue to be accumulated even in soils found below the alluvial fan.

From Kovda's studies (2) the development and migration of sodium carbonate in the natural solutions (soil and ground waters) are noted until mineralization, as a rule, is not more than 3-5 g/liter (independent of the characteristics of one or another zone). Where we have purely sodium carbonate salinization the maximum concentrations (if we exclude the solutions of sodium carbonate lakes) are still lower, of the order of 0.5-1 g/liter. When the extent of mineralization of natural waters increases above this threshold or limit (3-5 g/liter) the sodium carbonate in these waters disappears. This latter fact has not been satisfactorily explained until now. At the same time, when we evaluate this phenomenon from the general geochemical standpoint there appears probable (although still insufficiently understood in detail) an existence of a relationship between the limited possibilities for sodium carbonate accumulation near the earth's surface and the geochemical history of calcium in the earth's crust. In particular, the

¹Known centers of sodium carbonate salinization in North America and in several regions of North Africa are associated most often with the same conditions.

accumulation in all the geological epochs of large masses of calcium carbonate may be regarded in some cases as the result of a peculiar competition between calcium and sodium (the Clarke elements [numbers] which are relatively close) for the CO_3^{--} . One would think that a single, chemical reaction, which might lead in nature to the same results, is the reaction of sodium carbonate to gypsum. However, the sulfur content in the earth's crust is clearly insufficient for the formation everywhere of such large masses of gypsum, which would be required to realize this reaction. In addition gypsum under arid conditions is easily accumulated in the soil and subsoil and, obviously, is far from always being dispersed by the neutralization of sodium carbonates. Confusion arises as to how the neutralization of sodium carbonate, which is constantly being formed during the weathering of various rocks, occurs in nature. We may add to this that in the geological formations of the past we knew of no large accumulations of sodium carbonate. The appearance of this salt in the form of weak concentrated solutions in the mineral resources of the earth has recently been explained more often by the desulfurization phenomena of the salts of soil solutions, originating in the presence of oil (6, 1, and others). The fact has not been ruled out that sodium carbonate salinization on the earth in all geological epochs was unstable and could not be maintained for any length of time.

All of this is proof of the existence in the phenomena of sodium carbonate salinization of a number of still unsolved problems which have at the same time a great scientific and practical significance.

With regard to the material discussed, new data on sodium carbonate salinization which the author has succeeded in collecting in 1959, along with a group of Chinese (headed by Ven' Tszevan) and Soviet specialists in Southern Sin'tszyan, can be of obvious importance. To some extent these data will enable us to understand the nature of certain unusual phenomena which so often accompany the sodium carbonate salinization of soils.

Southern Sin'tszyan, as a whole, is an extremely dry land, located in the very center of drainless Central Asia. Being thousands of kilometers away from the world's oceans, it is alien in large measure to the effect of ocean air masses as the result of towering mountain structures, of which Eastern Tyan'-Shan' and Kun'lun' are particularly important. The Tarimskaya platform contained between them or the Tarimskaya basin, as it is usually called, is situated along with the foothills surrounding it in a peculiar aerodynamic shadow, formed by these mountain structures. For this reason the regions bordering the Kun'lun' are especially deficient in precipitation. The ocean air masses approaching Sin'tszyan from the west pass through here only at great heights. A very small amount of moisture, which these air masses carry, falls in the high mountain regions, principally in the form of snow. Various mountain rivers, which flow toward the foothills of the mountain ridges and then are lost in the Tarimskaya plain, are enriched by this precipitation (from small glaciers).

On the alluvial fans of these rivers we often find very old irrigated oases which have been separated from one another by desert foothills. From the landscape standpoint, these are exceptionally lifeless Central Asiatic Gobis. From the Tarimskaya plain the oases on the alluvial fans are suddenly replaced by the sands of the Takla-Makan desert; in the area oriented towards the mountains, the oases border upon scarcely less desert mountain slopes, which are to the very nival zone practically deprived of vegetation, particularly in Kun'lun'.

The extremely dry nature and the general drainless character of Southern Sin'tszyan create especially favorable conditions for an intensive salt accumulation at the foothills of the mountain structures, in particular, in the lower reaches of rivers. There is no doubt that they also affect weathering processes and the release of easily soluble salt elements, but we have no information to enable us to determine this.

The salt accumulation processes have been going on in this region for a very long time—from the end of the Mesozoic period, when the Tarimskiy basin first began to be formed into a drainless dry region (7, 4, 5).

The effect of the geological structure in different parts of the country, apart from climatic reasons, has influenced the specific characteristics of present day soil salinization in Southern Sin'tszyan. In this sense the following 3 large regions have been distinguished, namely: in the north—the southern slope of Tyan'-Shan'; in the west—the Kashgarskiy amphitheater (forming the Kzyl-su River basin, or, otherwise, the Kashgar-Dar'ya) and in the south—the northern Kun'lun'.

The southern slope of Tyan'-Shan' was formed by young Mezo- and Cenozoic folds and blocks considerably uplifted in the Alpine phase of orogenesis. The sedimentary layers comprising them were formed in the past within the piedmont depression zone in the Hercynian period of Tyan'-Shan', where not only the fine-earth products of rock weathering have been unloaded, but where at the same time different soluble compounds have been accumulated. For this reason, almost all the sedimentary layers which form the foothills of Eastern Tyan'-Shan', starting with the Cretaceous period, contain a large quantity of easily soluble salts as well as gypsum.

The principal water supply for the mountain rivers of the southern slope of Tyan'-shan', as in the entire Tarimskaya plain, originates in the high mountain glacial region. Flowing toward the Tarimskaya plain, the mountain rivers partially eroded the foremost Mezo-Cenozoic uplifts. Owing to this, the mountain river waters in the region of the foothills are additionally enriched by suspended matter and soluble compounds. Infrequent heavy showers, which sometimes occur in the foothills of Tyan'-Shan', likewise contribute to the enrichment of river runoff by these products. As a result, during individual periods the rivers of this region carry off onto the piedmont plain a large quantity of clay particles and easily soluble salts, which are attracted into the secondary migration cycles. During those periods of the year when river runoff is curtailed and supplied only by the precipitation in the high mountain zone, we note the appearance of sodium bicarbonate in the water of certain

Table 1

Chemical composition of waters of certain rivers of Southern Sin'tsryan flowing onto the plain (from single samples, summer of 1959)

Name of River	Region	Solid residue g/liter	Alkalinity		Cl	SO ₄	Ca	Mg	Na by difference
			CO ₃	HCO ₃					
			meq liter						
Akh-su ^a	(Tyan'-Shan')	0,52	0,25	1,15	2,02	2,36	2,55	1,30	1,93
Kyzyl-su ^a	(Kargarsk)	0,53	0,11	2,88	1,71	2,85	2,65	1,54	3,40
Kyzyl-su		1,83	None	4,41	7,01	15,52	11,38	5,62	9,95
Gez-dar'ya	Kun'lun'	0,81	0,34	3,02	1,87	7,29	6,73	3,82	1,96
Gez-dar'ya	"	0,45	None	2,92	1,87	1,75	2,51	0,29	3,75
Yarkend-dar'ya ^a	"	0,22	"	2,01	0,64	0,98	1,92	0,86	0,85
Yarkend-dar'ya	"	0,41	"	2,56	1,58	1,81	3,74	1,23	0,98
Yarkend-dar'ya	"	0,55	0,19	2,78	2,14	3,29	0,45	0,15	7,80
Reservoir									
Merget	"	1,34	0,39	2,88	7,96	8,96	0,04	0,71	19,44
Tiznap	"	0,89	0,20	3,76	4,51	2,67	3,04	5,67	2,42
Guma	"	1,00	0,47	4,48	6,91	5,29	2,78	4,54	9,83
Karakash-dar'ya	"	0,74	None	4,12	5,89	1,31	3,05	4,44	3,82
Karakash-dar'ya ^a	"	0,22	0,23	1,84	0,43	1,14	1,15	1,10	1,39
Yurunkash-dar'ya	"	0,474	None	3,00	1,90	1,90	2,40	1,80	2,70
Yurunkash-dar'ya ^a	"	0,37	0,17	2,23	1,36	2,10	2,44	1,29	2,13
Yurunkash-dar'ya	"	0,37	0,17	2,23	1,36	2,10	2,44	1,29	1,87
Yurunkash-dar'ya	"	1,1	None	4,9	7,80	3,19	2,87	2,73	10,4
Keriya	"	0,480	0,24	2,90	2,90	2,20	1,70	1,70	4,80
Keriya ^a	"	0,41	0,57	2,84	2,64	1,17	1,72	1,44	4,00
Niya	"	0,695	None	1,44	2,60	6,60	3,90	3,00	3,70

^aCollections by N. T. Kuznetsov.

^bNot including alkalinity of CO₃.

Note: Comma represents decimal point.

rivers (e.g., the Akh-su), even in the lower reaches.

In accordance with the overall geochemical situation, sulfate-chloride salinization is the principle form of soil salinization on the piedmont plains of Southern Tyan'-Shan'. However, in the mountain soils of the upper parts of certain alluvial fans we sometimes find a weak sodium carbonate salinization which is observed near the rivers (in the flood plain zone) where ground-water mineralization is not more than 0.5-1.0 g/liter. The development of sodium carbonate salinization under these conditions implies the participation in the present-day salt accumulation processes of also the most recent products of rock weathering.

The next geomorphological region, which forms the basin of the Kyzyl-su River, is situated at the junction of the Tyan'-Shan' and Kun'lun' mountain systems. This region also consists of a massive-crystalline mountain core, bordered by a complex of sedimentary rocks of different periods. This part of Southern Sin'tsryan is characterized by somewhat greater moisture as compared with the other areas. The removal of fragmental material is also realized here principally from the high mountain region. Somewhat better moisture conditions in the basin, possibly have had an effect upon rock weathering, because in the alluvium of the Kyzyl-su, there is a large quantity of clay particles. At the same time, more frequent

precipitation in the central mountain zone, although it does not alter the desert appearance of this area, will create certain opportunities for runoff and removal of even the ancient sedimentary layers. In particular, the reddish Paleogene clays which contain gypsum in spots (other salt bearing deposits are not known here) are periodically washed away in the basin. The runoff products of the sedimentary layers, along with the rock weathering products of the high mountain zone, are transported by the Kyzyl-su into the western Tarimskaya plain, where they form a complex of alluvial deposits with a predominance of clay loam. With the leaching of parent materials containing gypsum, the water of the Kyzyl-su is enriched noticeably by calcium sulfate. Another time sodium carbonates may be present in the water of the Kyzyl-su (Table 1).

Thus, the absence here of thick layers of ancient salt-bearing sedimentary rocks is (in the sense in which we are interested) the most important difference between the Kyzyl-su basin and the preceding region. In other respects, these 2 regions are very similar, even in the character of present-day salinization, despite some difference in the amount of precipitation. Thus, for example, despite the presence of salt-bearing rocks in Tyan'-Shan' and the absence of them in the Kyzyl-su basin, we find from time to time in their strictly water-logged zones a weak sodium carbonate and sulfate-sodium carbonate salinization; only on the alluvial fan of

Kyzyl-su does the salinization have more often a surface character (Profile No. 188). Downward along the slope this form of salinization disappears, being replaced by a chloride-sulfate form and, somewhat less often, by a sulfate-chloride form. At some distance from the mountains soil salinization in the lower reaches of the Kyzyl-su is as widespread and extensive as near the foothills of Tyan'-Shan'.

A more unusual situation is observed in the third region—along the northern framework of Kun'lun'. A complex of ancient sedimentary rocks has been developed also in the piedmont section of Kun'lun'. However, this rock strip is very narrow and descends abruptly toward the Tarimskaya plain. An almost total absence of precipitation in the foothills practically rules out the runoff and removal of these rocks. In addition, often they are very permeable to water because fine textured soils are missing among them. The fragmental material removed by the Kun'lun' Rivers is formed principally in the high mountain region and consists of the decomposition products of the massive-crystalline rocks of which granite has an important role. The disintegration of the rocks occurs under high mountain cold desert conditions and is accomplished under the influence chiefly of physical weathering factors. A lack of heat and an extreme suppression of the biological processes are not conducive to the formation and accumulation of any large amounts of clay and colloid particles in the final weathering products. In accordance with this, the suspended alluvium of the Kun'lun' Rivers consists principally of bound or associate sands, or of silty sandy loam containing no more than 4% clay (according to studies of N. T. Kuznetsov and O. A. Shchelyakina). This suspended alluvium has a very low adsorption capacity, of the order of 2 meq per 100 g of dry matter. Moreover, the freshly deposited alluvium on the alluvial fans, before becoming fixed by vegetation, is often subjected to the influence of aeolian processes. As a result, many deposits are becoming increasingly deficient in fine particles.

For these reasons the parent materials on the alluvial fans of the rivers of the northern slope of Kun'lun' are most frequently silty sands, which sets off this region sharply from the two previous ones.

Sodium bicarbonate is present chemically in the runoff of the Kun'lun' Rivers (Table 1).² The presence of sodium bicarbonate, not always clear from analyses of weak natural solutions, appears more distinctly in the concentration of river water. The composition of water in the Merget reservoir where the water of the Yarkend River is accumulated and partially evaporated is, particularly, proof of this. Thus, there exist well-known reasons for the development of sodium carbonate salinization near the

foothills of Kun'lun'. However, sodium carbonate salinization was developed here in such large measure that we could not explain it by this fact and so the need arose to examine the salt accumulation conditions in this region in somewhat greater detail.

First, let us dwell on the general characteristics of salt accumulation in the ground waters of several alluvial fans near the foothills of the Kun'lun' (Table 2). Water samples were selected in each thinning out zone of ground waters, where they evaporated and at the same time are concentrated. Under local conditions these zones of the water logged type have been greatly expanded, usually extending in unbroken massifs for many kilometers. This is explained by the slight water permeability of, and similarity in, the composition of the parent materials in connection with which the thinning out of ground waters occurs very gradually (only as the result of flattening of the slopes). A part of the ground waters is able to flow beyond the limits of the fans—onto the sands of the Takla-Makan desert. The absence of clay loam and clay rules out the formation here of water-logged zones, in the narrow sense, and of the dispersion zones of ground waters following this. No specially high concentrations of salt in the ground waters result in this situation, despite a considerably dry climate. At the same time, the spatial differentiation of salts appears in a weakened form. All the waters, starting from the upper strips of the thinning out zone where salt accumulation is only beginning, and to the very lowest strips of the zone—on the diluvial deposit strips of the fans, reveal a mixed salt composition. In this sense the sodium carbonate content in these waters does not represent an exception. Contrary to expectations, the amount of sodium carbonate in the solutions increases, in turn, with the increase in the concentration of the solutions to the point of attaining a total mineralization of the order of 10-11 g/liter (Table 2, samples No. 36, 38). Subsequently, sodium carbonate accumulation, as compared with the accumulation rates of other salts, will slow down, but the absolute amount of sodium carbonate will continue to increase roughly to a mineralization of 18-24 g/liter (sample 58a).

The analysis of sample 110 given in Table 2 deserves special attention. The sample was taken from a soil profile number on the Yarkend River alluvial plain almost 200 kilometers from the point at which the river left the mountains. The conditions for changing the solution, in this case, are somewhat different than those on the alluvial fans. Consequently, the total water mineralization was very high—more than 70 g/liter. Despite this fact, signs of normal sodium carbonate are still being detected in the solution (by the reaction to phenolphthalein). Apparently, sodium carbonate accumulation and migration processes under local conditions are developed under the influence of some specific principles which are not directly related to the readily water permeability of the parent materials, or to conditions of ground-water discharge.

The composition of easily soluble salts in the soils at the same points from which the ground waters have been taken (Table 3) shows that large quantities of sodium carbonate, with a sodium carbonate concentration in the form of

²Samples subject to analysis were taken in the summer of 1959. Part of samples were taken in hydrology expedition by N. T. Kuznetsov. Analyses were made by the soil chemists of the Soil and Hydrology Branch of Sin'tszyan Expedition of the Chinese National Republic.

Table 2

Chemical composition of ground waters on the alluvial fans of Kun'lun' Rivers

Sample Number	Lower reaches of the river	Depth from the surface, cm	Solid residue, g/liter	Alkalinity		Cl	SO ₄	Ca	Mg	Na by difference
				CO ₃	HCO ₃					
				Meq per liter of solution						
36	Niya	134	10,5	None	24,8	49,6	82,3	5,6	88,6	62,5
38	Keriya	69	10,9	"	36,1	15,6	103,8	1,2	27,6	126,7
46a	Karakash	107	17,6	"	37,5	185,9	52,8	3,4	41,0	231,8
58	Karakash	137	24,0	"	38,7	249,0	82,6	0,6	84,1	285,6
188	Gez-dar'ya	163	13,8	"	10,7	13,3	81,4	30,4	47,9	27,1
110	Yarkend ^a	160	76,1	0,3	11,8	888,6	271,5	42,5	218,1	911,3

^aSample taken on the Yarkend alluvial plain.
Note: Comma represents decimal point.

normal salt, chiefly in the uppermost horizon, are accumulated (along with other salts) in the soils. A mixed sodium carbonate sulfate-chloride salinization of soils is observed both on virgin lands and on recently reclaimed areas of state farms over the entire stretch of the thinning out zones, which as mentioned previously, include the diluvial deposit strips of the alluvial fans. On the soils of ancient irrigated oases the content of salts, including sodium carbonate, is reduced considerably, but the weak spotty sulfate-sodium carbonate salinization is found even here.

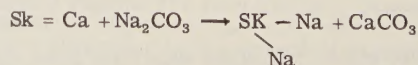
In order to analyze further the specific characteristics of sodium carbonate salinization at the foothills of Kun'lun' it is very important to note the somewhat different situation and forms of sodium carbonate salinization on the alluvial fan and alluvial plain of Gez-dar'ya. This river basin is situated in the western, somewhat more humid, part of the Kun'lun' mountain system. This fact does not essentially affect the enrichment character of the Gez-dar'ya which receives its water supply almost entirely from the melting of glaciers. However, it seems that rock weathering leads to somewhat different results here, because there are more clay particles in the alluvium of Gez-dar'ya than in the alluvium of the other rivers of the same region. In connection with this, we find in the lower reaches of this river clay loam deposits which are absent in the alluvial fans farther to the east. At the same time, soil and ground-water salinization is developed here somewhat differently. In particular, the sodium carbonate salinization has a more limited distribution. It develops only in the beginning of the water-logged zone, while below, it gradually disappears, being replaced by other forms. These forms emerge and on the fan of the Gez-dar'ya pursue the same pattern observed in other regions beyond the Kun'lun'. In addition, gypsum in the form of fine rare druse is being detected in subsoils in the zone of intensive chloride-sulfate salinization (on the Gez-dar'-ya alluvial plain).

Thus, in the lower reaches of the Gez-dar'ya, we see a pattern, normally expected with sodium carbonate, of spatial salt differentiation and interchange of salt zones. At the same time, new, still little known patterns in

the development of sodium carbonate salinization are being recorded on the other alluvial fans near the foothills of Kun'lun'.

Since the texture of water-bearing and soil-forming parent materials is the only essential difference between strong sodium carbonate salinization regions near the foothills of the Kun'lun' and the other regions, the question arises as to whether these materials, for example, clay and clay loam, can directly affect the composition of natural solutions, including the sodium carbonate content in them. We should give an affirmative answer to this question, based, first of all, on the tendency of finely dispersed materials (owing to the presence of colloid particles in them) toward exchange physicochemical reactions with cations, which wash the colloid particles of the solutions. No other factor, including the well-defined water permeability of the parent materials, is able to have the same profound effect on the qualitative composition of the natural solutions.

We know that the colloid or adsorbing complex of most soils and parent materials, especially in the dry zones, is saturated chiefly by calcium. The total content of this element found in a physicochemical relationship with colloids in the earth's crust, should be extremely high. There may be about 7 kg of calcium to one metric ton of clay loam material. The composition of the low concentrated natural solutions which interact with the parent materials usually favors the maintenance of the predominant role of this cation amidst the exchangeable bases. This is due to the fact that, in relation to the other cations, there is always a significant fraction of calcium in the weak solutions. We observe a different situation with sodium carbonate in the solutions. In this case, exchangeable calcium, being displaced by sodium into the solution, is rapidly bonded by the free CO₃⁻⁻ into an almost insoluble salt, according to the following scheme:



Owing to the bonding or fixation of the displaced calcium, the reaction rate becomes primarily one-sided, which facilitates further introduction of sodium onto the surface of the particles. The removal of sodium carbonate is

SODIUM CARBONATE SALINIZATION

Table 3

Composition of water extracts from soils on alluvial fans of Kun'lun' Rivers (with 3-minute shaking)

Profile number	Oasis	Depth, cm	Solid residue, %	Content of ions in meq per 100 g of absolutely dry soil						
				CO ₃	HCO ₃ ^a	Cl	SO ₄	Ca	Mg	Na by difference
36	Niya	0—1	30,6	0,30	1,70	114,85	333,46	15,75	237,91	196,35
		1—20	1,1	0,20	0,30	8,34	8,27	1,30	7,32	8,29
		20—49	1,1	None	0,33	8,59	9,33	2,95	6,58	8,72
		49—64	0,9	0,07	0,25	3,72	10,06	4,25	4,28	5,50
		64—80	1,2	0,07	0,21	3,07	13,50	7,45	4,85	4,48
		80—180	1,2	Trace	0,28	2,20	13,50	10,60	2,55	2,83
38	Keriya	0—2	6,1	17,47	18,39	66,58	19,65	0,50	7,89	96,14
		2—12	0,6	0,27	2,11	7,06	1,04	0,40	0,90	8,75
		12—20	0,7	1,72	2,23	6,12	2,23	0,10	1,07	9,49
		20—31	0,2	0,07	0,75	2,20	0,63	0,30	0,33	2,90
		31—44	0,2	0,03	0,69	1,38	0,73	0,50	0,58	1,70
		44—59	0,3	0,30	1,03	1,89	0,96	0,10	1,07	2,55
		59—76	0,2	0,17	0,50	0,90	1,02	0,10	0,58	1,65
46	Khotan (Karakash-dar'ya)	0—1	29,3	9,23	4,82	115,23	290,04	0,40	7,07	402,62
		1—10	2,9	2,17	1,20	26,87	14,81	0,10	1,40	41,48
		10—21	1,8	1,10	0,90	18,73	7,38	0,10	1,07	25,84
		21—46	0,8	0,13	1,07	9,61	1,85	0,30	0,44	11,82
		46—69	0,8	0,77	0,61	8,14	3,54	0,15	0,41	11,73
		69—100	0,7	0,50	0,51	6,90	3,17	0,10	0,33	10,15
		100—108	0,27	0,51	6,03	1,90	0,15	0,49	0,49	7,80
188	Gez-dar'ya	0—1	39,6	2,24	3,84	79,61	471,59	1,75	340,92	212,37
		1—2	13,8	1,09	2,26	17,83	175,35	14,75	113,64	67,05
		2—21	2,5	None	0,29	5,80	26,18	12,75	10,20	9,32
		21—34	2,0	"	0,33	3,63	21,97	13,75	6,08	6,10
		34—45	1,5	"	0,25	1,44	18,02	12,95	4,11	2,65
		45—61	1,5	"	0,28	1,18	18,52	14,55	2,71	2,72
		61—103	1,3	"	0,23	1,27	16,79	12,00	3,78	2,51
		103—110	1,5	"	0,54	1,35	17,29	15,15	3,04	0,99
		110—150	1,2	"	0,29	0,53	14,81	13,85	1,64	0,14

^aNot including alkalinity of CO₃.

Note: Comma represents decimal point.

a result of this reaction, which takes place similar to the exchange reaction between two salts (with the only difference being that a colloid particle in place of a second anion participates in the reaction). Sodium carbonate is eliminated almost in the same way as during sodium carbonate interaction with gypsum.

At the same time the possibilities of neutralizing sodium carbonate by this means has greater prospects than by using gypsum which is comparatively rare and not found in all zones. We must consider that clay loam and clay rocks saturated to some degree by Ca⁺⁺ are found practically everywhere. The possibility of the effect of physicochemical reactions on the com-

position of underground waters has been noted (V. A. Sulin, L. V. Pustavalov, V. A. Priklonskiy, V. A. Kovda, T. A. Gevel'son, and others); however, the scale of these phenomena has seldom been recognized as important or significant. They have not been considered in problems associated with the history of sodium carbonate salinization. If we admit that the exchange reactions are a great geochemical factor, in some cases we may easily avoid many difficulties which have arisen in explaining the peculiar appearances of sodium carbonate salinization. In particular, the following fact, which has previously not been properly understood, can now be explained (at least under the piedmont plain conditions). When the natural

solutions which salinize the soil contain other sodium salts besides sodium carbonate, a gradual or systematic concentration of salts during a stable (constant) binding of a large part of the calcium displaced from the exchange state (and, possibly a part of magnesium) will lead to an ever increasing predominance of sodium compounds in the solutions. The predominance of sodium even after the disappearance of sodium carbonate may, for a long time, contribute to an irreversible displacement into the solution of adsorbed calcium to the extent that mineralized subsoil solutions travel through the local gradient. In the absence of the free CO_3^{--} the displaced calcium begins to be combined, in the first place, with the SO_4 ion, which leads to the formation of gypsum. As the solutions are saturated by this newly formed compound, gypsum begins to be deposited in the solid phase of the soils which will most probably be observed below the zone of sulfate-sodium salinization. Thus, the unknown origin of this salt below the region of sodium carbonate salinization is cleared up; it is likewise concealed by the presence of exchange reactions.

The ideas expressed here agree well with the results of certain experimental studies on the behavior of sodium carbonate solutions in the soils. In this regard we shall mention the very interesting study by Krupkin (3) who has established the following from experiments with monoliths of leached chernozem. The movement of sodium carbonate solutions upward through the capillaries occurs somewhat differently than in solutions of other salts. Sodium carbonate travels not only slower, but is separated from the liquid phase being retained in the lowermost horizon. After this a part of the water travels upward, becoming free of this salt. The author accurately explains the results which he obtained by the fact that the sodium of the sodium carbonate is removed from the solution as a result of the exchange reaction. The free CO_3^{--} is dispersed by the formation of calcium carbonate. A further rise upward of the sodium carbonate in the solution becomes possible only after the saturation of the lower layer of the monolith by exchangeable sodium. Calcium chloride was detected in the soil after a short time in another experiment with a solution of sodium chloride. The upward movement of this calcium chloride has anticipated the movement of the initial solution. In a third experiment, where a solution of sodium sulfate was used, gypsum, missing until now, was accumulated in the soil. The peculiar role of the exchange physicochemical reactions in transforming the composition of underground waters and, in like manner, the possibility of directly removing the sodium carbonate from the solutions during their interaction with soils and rocks, has been established in the best way possible by these studies. Data of a similar nature has already been published in an earlier report by O. A. Grabovskaya.

Coming back to a more precise definition of the causes of the peculiar development of sodium carbonate salinization in soils on the piedmont plains of Kun'lun', we might say that the here-noted deviations from the usual patterns of soil and ground-water salinization forms are entirely explained by the absence of clay parti-

cles among the soil-forming and water-containing parent materials. A variation in the other natural factors over the vast area of Southern Sin'tszyan, e.g., the chemical composition of river water, the varied composition of ancient sedimentary rocks which participate in the formation of the most recent continental deposits, etc., has had no effect on the character and forms of sodium carbonate salinization in the area under study. Thus, the preceding data enables us to become firmly convinced of the exceptionally large role of clay and other fine particle materials in the phenomena of removing or arresting the sodium carbonate salinization of soils. It is very probable that if there were no large masses of finely dispersed deposits on the earth long ago, sodium carbonate salinization would have become so widespread that, inevitably, it would have had an effect upon the entire history of the development of the plant world.

In conclusion, we might dwell on several practical results which have been arrived at from the foregoing discussion. First of all, it is obvious that it would be easy to remove sodium carbonate salinization on soils characterized by an especially coarse texture (consequently, not capable of a significant development of physicochemical reactions or of solonetization) by employing ordinary leaching. It is not by chance that the control of sodium carbonate salinization in the oases near the foothills of Kun'lun' has been based until now on traditional methods of soil desalinization-by the leaching of part of the land, based on so-called dry drainage, when only a part of the suitable area is reclaimed, while the other part carries out the function of a ground-water evaporator and becomes salinized. To achieve a more successful result, the local population also used the following method which deserves our attention. Before spring pre-sowing leaching, which is required practically every year by the naturally undrained lands in Southern Sin'tszyan, organic fertilizers well enriched with compost (sometimes prepared by another means), are added to the fields. These fertilizers, by beginning to decompose rapidly even before sowing (which is carried out late here),³ contribute to the saturation of the plowed layer by carbon dioxide. In the presence of carbon dioxide, normal sodium carbonate becomes a bicarbonate, which is more easily leached, but the main point is that it does not create a dangerous alkalinity of the soil solutions, which as we know has an especially destructive effect on the sprouts of cultivated crops. When there is an excess of carbon dioxide, the pH of the solutions of alkaline soils often becomes neutral and even weakly acidic. The addition of organic fertilizers during sodium carbonate is a successful measure being employed by the local people. We should also point out that carbon dioxide saturation of sodium carbonate-salinized soils (this idea was expressed by V. A. Kovda), generally speaking, may become a future means of controlling sodium carbonate salinization.

This material leaves many meliorative problems still facing agricultural production in Southern Sin'tszyan and does not give a full

³ Because of lack of spring flood water.

picture of the soil salinization characteristics in this region of Central Asia.

The purpose of this article has been to attract great attention to the problems of the sodium carbonate salinization of soils, by using the very rewarding material gathered in the Tarimskiy basin. These data show how great the effect of sedimentary rocks can be on the qualitative characteristics of present day soil salinization, especially by sodium carbonate.

The appearance in Southern Sin'tszyan of a new, very unusual area of chloride-sulfate sodium carbonate salinization may be of great interest.

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SALT ACCUMULATION IN SOILS OF THE DNIESTER MARSHLANDS AND THE PRINCIPLE OF THEIR REGIONALIZATION¹

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In the southern Ukrainian SSR the bottomlands of the Dniester River and its tributary, Turunchuk, cover 27,000 ha. The possibility of reclaiming them agriculturally is determined by a complex of natural historical conditions. Their relief is the principal factor responsible for the meliorative qualities of the river bottomlands. The frequency and duration of flooding depend upon the elevation of the bottomlands above the mean low level of the river (level of the river in the period following spring flooding). This same factor determines the possibility of ground-water flow into the river and, consequently, the degree of water-logging and salinization of the bottomlands.

Both the alluvial processes (deposit of suspended particles by water during rapid flow) and the flooding processes (deposit of suspended particles by slow-moving or standing water, already freed of coarse suspended matter) take part in the development of the relief. The relief is developed more rapidly when the alluvial processes are predominant rather than when the flooding processes prevail. The flooding processes play an ever decreasing role, as the dry land increases, yielding to the alluvial processes. At the same time, in the alluvial deposits the coarser fractions of texture begin to become predominant.

We can judge which processes play the leading role in the development of the relief by the change in soil texture by depth in the various parts of the flooded areas.

Table 1 presents data on the texture of bottomland soils of the upper, middle and lower courses of a given river strip. At the upper course the surface layers of the soils along the river are composed of coarser particles than the deeper-lying layers; in the interior, on the other hand, the upper layers have a finer texture than the lower layers. Consequently, the alluvial processes share in the structure only along the river. The interior is developed under flood conditions. As the part along the river increases, the

flow of flood waters onto the bottomlands becomes more difficult; thus we find continually more purified waters, deprived of coarse suspended particles. Consequently, the finer particles settle there, as opposed to the part along the river.

Along the river part of the bottomlands of the middle course we observe fine-textured soil layers alternating vertically with coarser layers. The alluvial processes become weaker as we move toward the inland bottomlands and the flooding processes replace the alluvial. It is possible to judge of the predominant role of the flooding processes in the development of the relief of inland bottomlands by the occurrence (deposit) of the fine textured layers on the coarser layers. At the lower course the flooding processes share in the formation of the relief of not only the interior but also along the river part (Table 1).

Thus, development of the relief of Dniester bottomlands in the southern Ukrainian SSR against a background of epeirogenic subsidence is due basically to flood conditions which have led to a relatively weak development of relief on the given strip. This can be seen from the data in Table 2.

The upper course along the river is more developed than on the rest of the bottomland area. Here, it is 3 m higher than the interior, whereas at the lower course the part along the river is only 1.2 m higher. The difference between the minimal levels (heights) of the bottomlands and the mean low level at the upper course is able, in some measure, to ensure ground water flow into the river, although at some interval of time between floods. At the lower course this is impossible. Here, on the contrary, there is a pressure head of river and estuarial waters because the mean low level is above the minimal levels (heights) of the bottomlands.

The extent to which the relief is developed determines the water regime of the bottomlands and, hence, the types of soil formation. The relief of the bottomlands of a given length of river had been only slightly developed. At the upper course where it has been developed more than at the lower, the meadow type is predominant; at the middle course the bog

¹ Field investigations were conducted by Soil Scientist L. O. Goryacheva of the Odessa Branch.

SALT ACCUMULATION

Table 1

Data on the particle-size analysis of Dniester bottomland soils (after the method of N. A. Kachinsky), %

Location of Profile Nos.	Profile No.	Depth, cm	Particle-diameter, mm							
			>0,25	0,25— 0,05	0,05— 0,01	0,01— 0,005	0,005 0,001	<0,001	<0,01	
Upper course, Severnyy Turunchuk island	Meadow, slightly salinized soils along river part of island									
	327	0—20	0,31	28,11	46,49	7,24	7,65	10,20	25,09	
		20—40	0,42	22,65	42,28	9,73	7,48	17,44	34,65	
		100—120	0,10	10,46	42,57	12,60	13,94	20,33	46,87	
	Bog, slightly salinized soils, interior of island									
	241	0—20	0,94	3,97	7,77	6,36	32,58	48,38	87,32	
		40—60	0,77	3,53	16,38	5,46	29,56	44,30	79,32	
		80—100	0,69	9,66	24,89	11,51	23,79	29,46	64,76	
	Middle course, Yuzhnyy Turunchuk island	Meadow, moderately salinized soils along river part of island								
		620	0—15	0,64	25,71	23,98	8,27	13,64	27,73	49,64
32—50			—	12,42	29,37	6,72	15,22	36,27	58,21	
95—115			—	11,38	46,60	9,66	9,67	22,69	42,02	
Peat-bog, moderately salinized soils, interior of island										
67		0—20	4,11	3,54	46,45	11,83	19,87	14,15	46,90	
		60—80	—	16,13	50,67	10,32	14,56	8,32	33,20	
		80—100	0,17	15,87	51,80	9,45	15,58	7,13	32,16	
Lower course, Glubokiyy Turunchuk island		Meadow, slightly salinized soils along river part of bottomlands								
		533	0—20	0,40	11,55	23,89	12,23	16,64	35,29	64,16
	40—60		0,11	11,76	26,70	10,56	15,13	35,74	61,43	
	60—80		0,13	9,67	20,14	11,63	13,00	35,19	59,82	
	Bog, salinized soils, interior of marshlands									
	498a	0—20	0,26	10,96	26,12	11,17	15,62	35,87	62,66	
		20—40	0,69	8,65	25,52	9,40	19,81	35,93	65,44	
		60—80	0,15	3,49	33,71	10,52	16,75	35,38	62,65	

Note: Comma represents decimal point.

and partly peat bog type prevail, while peat bogs are widespread at the lower course which is characterized by the greatest moisture. Meadow soils are found along the river zone of all sections of bottomland. Thus, the soil changes along the course of the river as well as from the river part of the bottomland toward the interior.

The peat bogs and peat bog soils cover 31% of the bottomland area, the bog soils 22%, and the meadow soils 27%. Hence, it follows that three-quarters of the Dniester bottomland area in the southern Ukraine is characterized by moisture while half is covered by peat bogs and peat bog soils. The excess moisture depends not only upon the slight degree to which the relief is developed but also upon the frequency of floods. Besides the spring floods, the summer floods occur annually.

The soils of the different soil-formation types differ from one another in their physical properties. In peat bogs with a 1.5-2.0 m thick peat layer the maximum field moisture capacity is 330%-350% of the weight, whereas, in meadow soils it varies between 25% and 35% depending upon texture.

The same geomorphological factor which determines the water regime of bottomlands and the type of soil formation is responsible for the development and decreasing of the salt accumulation process in the bottomlands and ground waters. Thus, ground-water mineralization is least in the bottomlands of the upper course. On the island of Severnyy Turunchuk mineralization is less than 1 g/liter, while on the inland bottomlands of the upper course mineralization is as much as 2 g/liter. The greatest mineralization is observed at the

Table 2
Topographic indicators of the Dniester bottomlands in southern Ukrainian SSR

Course of given river length (strip)	Marshlands	Absolute heights, m		Mean low level	Difference between minimal levels (heights) and mean low level
		Maximal (ridge)	Minimal (inland bottom-lands)		
		a	b	c	(b-c)
Upper course	Severnnyy Turunchuk Island Budilovskiye, Putrino	3,0	0,0	-0,2	+0,2
Middle course	Sredniy and Yuzhnyy Turunchuk Islands, Pisarskiye, Kvashino	1,0	-0,3	—	—
Lower course	Northern lighthouses (beacons), southern lighthouses, or beacons, Karagal'skiye, Nizkiye, Nadli-mannyye, Glubokiy Turunchuk island	0,5	-0,7	-0,5	-0,2

Note: Comma represents decimal point.

Table 3

Data on the analyses of water extracts from soils of the Dniester bottomlands (bottomlands above estuaries) in the zone of progressive salinization, mg per 100 g

Soils	Pro-file No.	Depth, cm	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁼	Ca ⁺⁺	Mg ⁺⁺	Na ⁺ + K ⁺	Dry residue
Thick, strongly salinized peat bogs of the lowest bottomlands	8	0—20	34	77	129	60	4	46	350
		20—40	27	110	230	144	18	14	593
		40—60	24	157	700	312	32	27	1253
		60—80	21	270	854	324	10	200	1679
		80—100	18	275	756	351	36	74	1510
		100—120	21	362	945	304	10	329	1971
		120—140	21	325	806	418	13	96	1679
Moderately salinized, fine clay loam, peat bog soils of the low bottom-lands	42	0—10	33	150	150	52	15	93	493
		20—30	37	170	150	52	15	106	630
Meadow, moderately salinized fine clay loam soils along the river section of the Dniester	50	0—10	56	190	125	12	1	187	571
		20—30	43	110	50	10	1	98	312
		60—70	33	140	55	15	1	111	355

lower course where sometimes it is more than 10 g/liter. Mineralization is especially high here in the lower interior area of the bottomlands, which is characteristic of regions of accumulation.

The same pattern is observed in the distribution of the extent of soil salinization. Three zones may be distinguished by this feature: the first zone — a relatively drained zone or a zone of unstable desalinization at the upper

course; the second zone — a slightly drained zone or a salinization zone alternating with desalinization at the middle course; and the third zone — an undrained zone or a zone of progressive salinization at the lower course. Soil salinization in each of these zones has its own specific characteristics.

The soil in the progressive salinization zone is chiefly peat bog, covering the low part of the bottomlands; we find peat bog soils on the

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higher bottomland areas, while meadow soils are found along the river.

Salt accumulation is most clearly pronounced in the lower part of interior. Here we see a great accumulation of salt in the peat bogs. The bulk of the salt is calcium and sodium sulfate and chloride. The upper layers are less salinized. The enormous quantities of water flowing onto the low bottomlands are conducive to a certain movement or displacement of salt from the upper layers into the lower. Desalinization does not take place because of the absence of natural drainage. We see in the lower layers an increase in salt content — up to 2%. Here the chloride and sodium content increase. In the salt composition of peat bog soils the chloride and sodium content is somewhat higher than that of calcium and sulfate. The salt composition of the meadow soils of the higher part along the river is principally chlorides and sodium followed by sulfates. The qualitative salt composition and salt concentration in the upper layer of the soil point to the progressive character of salinization. Although these soils are found near the river, the draining action of the river does not affect them. The river is situated high with respect to the bottomland. Under these non-runoff or closed drainage conditions, despite the flooded state of the bottomlands, a very strong accumulative tendency of peat becomes apparent. The moisture holding capacity of peat is high. Along with an enormous amount of moisture the peat also absorbs large quantities of salt (Table 3).

In a certain area of the zone the rate of salt accumulation is dependent upon the infiltration of estuarial waters having a somewhat

high mineralization.

We see a lower salt content in the soils in the second zone, as compared with the zone of progressive salinization found at the lower course of the river. The qualitative salt composition also changes — the calcium sulfates and bicarbonates begin to become predominant. The 2 sulfate maximums are not clearly expressed in the salt profile. The composition and distribution of salt throughout the profile indicate a combination of salinization and desalinization processes. In the peat soils of this zone the salt content is high. The accumulative action or effect of peat is still great (Table 4). As compared with the preceding zone this effect is less important. The salts are concentrated at a depth below 40 cm. Consequently, natural drainage is still inadequate and does not ensure the leaching of the salt. But in the higher part along the river area this leaching is observed. In the meadow coarse clay loam soils found here the salt content is less than 0.1%. The calcium bicarbonates and sulfates are predominant (Profile No. 304).

At the upper course the natural drainage of the bottomlands improves with the development of the relief and we observe soil desalinization not only along the river section but also along the inland bottomlands. The salt content is not more than 0.2%, i. e., the soils may be considered as nonsaline. The qualitative composition of salt also leads to the same conclusion. The salts are principally calcium bicarbonates and sulfates. Small quantities of sodium and chloride are found at a certain depth. This fact is very important: a change in the water regime inevitably leads to a redistribution of salt and to an enrichment of the upper soil layers by sodium chlorides and sulfates (Table 5).

Table 4

Data on the analyses of water extracts from soils of the Dniester bottomlands in the zone of mixed salinization and desalinization, mg/100 g

Soils	Profile No.	Depth, cm	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁼	Ca ⁺⁺	Mg ⁺⁺	Na ⁺ +K ⁺	Total salt
Bog, slightly salinized clay soils	314	0—20	43	12	56	35	2	7	155
		20—40	58	25	37	37	2	10	170
		80—100	55	25	50	40	5	6	181
Meadow, coarse clay loam soils	304	0—20	40	3	21	16	1	8	89
		40—60	43	4	4	14	1	3	69
		80—100	43	11	14	24	1	1	94
Thick, moderately salinized peat bogs	90	0—20	43	65	187	82	3	51	431
		20—40	24	70	215	90	5	45	449
		40—60	24	70	455	192	12	29	782
		60—80	31	80	586	224	7	73	1001
		80—100	21	80	385	121	9	88	704
		100—120	51	65	664	260	17	48	1105
		120—140	24	70	720	304	10	32	1160
		140—200	23	80	562	231	7	52	955

Table 5

Data on the analyses of water extracts from soils of the Pridunayskiye bottomlands in the zone of unstable desalinization, the Severnyy Turunchuk Island (mg per 100 g)

Soils	Profile No.	Depth, cm	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁼	Ca ⁺⁺	Mg ⁺⁺	Na ⁺ +K ⁺	Total salts
Bog-clay soils of the low bottomlands	87	0—20	27	19	28	24	2	5	105
		20—40	24	18	45	35	1	1	124
		40—60	23	14	44	44	2	1	129
		60—80	23	12	44	32	1	1	113
		80—100	23	12	90	48	2	2	177
		100—120	26	18	44	33	1	3	125
Meadow, slightly salinized clay soils	1	0—10	30	9	10	16	1	2	68
		30—40	28	18	18	18	1	2	75
		60—70	32	24	12	18	1	11	98
		90—100	34	22	16	12	1	58	143
		140—150	32	22	15	12	1	18	100

This served as the basis for defining this zone as a zone of unstable desalinization.

By comparing the salt accumulation characteristics in the soils of the Dniester bottomlands, it is possible to establish conditions under which this process takes place. The predominance of the flooding processes over the alluvial processes was used as the reason for the weak development of the bottomland relief and for its poor drainage, and at the lower course for the complete absence of drainage. For this reason, the soils formed on the strip of Dniester bottomlands under study have a fine texture. Only along the river zone of the upper part of the strip do the soils have a coarser texture. We see a finer texture in the

soils of the inland bottomlands. This, in turn, impairs their drainage. Peat bogs which accumulate large quantities of salt are widespread at the middle and lower courses. The specific characteristics of peat bogs — a high moisture capacity, low discharge water coefficient and a negligible capillarity, enable them to accumulate and retain salt.

All of these factors — the extent of drainage, texture, the accumulative tendency of peat — do not exist in the same degree in all 3 zones or even in the different parts of 1 zone. Depending upon the intensity of these factors there is a greater salt accumulation in the bottomlands of the lower course and a lesser accumulation in the bottomlands of the upper

Table 6

Data on the analyses of water extracts from soils of the Yasskaya manured field, mg/100 g

Soils	Profile No.	Depth, cm	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁼	Ca ⁺⁺	Mg ⁺⁺	Na ⁺ +K ⁺	Total salts
Bog, slightly salinized clay soils	616	0—20		25	37	—	—	—	—
		37—46		8	53	—	—	—	—
		60—75		223	631	—	—	—	—
		138—150		69	100	—	—	—	—
Meadow, slightly salinized medium clay loam soils	452	0—20	37	103	142	32	1	115	430
		20—40	42	32	45	10	3	44	176
		40—60	46	24	50	10	1	43	174
Meadow, strongly salinized medium clay loam soils	40	0—10	15	280	110	16	1	219	641
		40—50	21	410	300	66	4	336	1137
		140—150	27	390	120	25	3	287	852

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course. In addition, salt accumulation increases as we move from the area along the river toward the interior.

The character of salt accumulation also changes with an increase in the degree of salinization. At the upper course calcium sulfates and biocarbonates are predominant, at the middle course sodium and calcium sulfates, and at the lower course sodium and calcium chlorides and sulfates.

In resolving the problem of reclaiming the Dniester bottomlands, we must bear in mind the possibility of their secondary salinization after stopping the flow of flood waters and draining the bottomlands. As proof we can cite the progressive salinization of the soils along the river part of the bottomlands of the lower course, bordering the flooded peat bogs (Table 3). We also observe the salinization of the meadow soils of the Yasskaya manured field. A large area of this field is presently not undergoing flooding. In the low waterlogged section of the manured field which is being flooded, the soils are salinized to a depth below 0.5 m. In the area adjacent to these soils we note a progressive sulfate-chloride, calcium-sodium salinization of the surface layers. On the higher elements of the relief the salinization has acquired a chloride-sodium character. Included in this salinization is a fairly deep layer of soil extending downward 1.5 m and more from the surface (Table 6). Such deep salinization usually takes place whenever the mineralized ground waters subside as a result of a change in the water regime, but the ground-water level will remain above the critical point.

Thus, the drying up of the bottomlands leads not only to an increase in salt content but also to seizure by the salts of a thicker soil layer and to a change in the qualitative composition of the salts toward intensifying their toxicity. We also observe secondary salinization which is due to improper use of irrigation in the soils of the "old plowed" strip.

Based on these facts we may assume that we need to drain the bottomlands only to the extent of not disrupting the meadow regime whereby the subsoil moisture of soils is preserved, and ground-water desalinization favored by ground-water desalinization favored by ground-water flow and intake of fresh waters. Such a water regime may take place by regulating the flow of flood waters onto the sunken bottomlands through sluices and by a shallow drainage network. The depth of the drainage network should be such that the ground waters will not drop below the critical level, as Rozanov (3), Kovda, Yegorov, and others (1) have suggested.

The same water regime may be established also by means of rice plantings when there is a deep fault drainage (2).

A meliorative regionalization of the Dniester bottomlands in the southern Ukrainian SSR has been based, first of all, on a geomorphological principle which determines the extent of natural drainage and, consequently, the direction and rate of the salt accumulation process in the soils. According to this criterion all the bottomlands are divided into 3 parts: those of

the upper, middle, and lower courses. In addition, we are taking into account the relationship between the bottomlands and the main shore, i. e., in each part we must divide the bottomlands into inland and insular areas. We cannot lose sight of such an important feature as the peat development of the bottomlands.

In this meliorative regionalization we must divide into separate regions the bottomlands which contain soils involved in secondary salinization.

Based on the foregoing characteristics the Dniester bottomlands in the southern Ukraine are subdivided into the following meliorative regions:

Region No.	Bottomland strip by course	Character of bottomland	Stage of salt accumulation
1	Upper course	inland	Unstable desalinization
2	the same	insular	the same
	Middle course	insular	Mixture of desalinization and salinization
4	the same	the same	Weak salt accumulation by peat
5	the same	inland	Mixture of desalinization and salinization, and a superimposition on them of secondary salinization
6	the same	the same	Secondary salinization as a result of drying
7	Lower course	inland	Progressive salinization and a considerable accumulation of salt by peat
8	the same	insular	

Conclusions

The meliorative qualities of the Dniester bottomlands in the southern Ukrainian SSR are determined by their relief, i. e., by their height above the mean low level of the river. The development of dry land depends upon the relationship between the intensity of the alluvial and flooding processes. In the Dniester bottomlands in the southern Ukraine the flooding processes are predominant, which is the reason for the retarded development of dry land and for the poor drainage of the bottomlands. Favorable conditions have been created here for salt accumulation. Only at the upper course of this river strip do we observe an unstable desalinization. The rest is enveloped in various stages of salt accumulation. The accumulative tendency or capacity of peat favors the salt accumulation

process in the bottomlands of the lower and, partly, of the middle courses. Salinization takes place as the result of soil drying. The Dniester bottomlands have been divided into 8 meliorative regions on the basis of geomorphological characteristics and soil salinization stages.

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MOISTURE REGIME OF DARK-BROWN FOREST SOILS IN WALNUT FORESTS

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The walnut forests of Southern Kirgizia are of great importance to the economy of our country. The Academy of Sciences of the USSR first began its comprehensive studies of walnut forests in 1944-1945. The results were published in the works of the expedition (15). To solve problems requiring long-term observation, a walnut scientific-research station was established in 1946.

The present paper is based on the results of 3 years of observation at the S. M. Kirov walnut forest. The observations were conducted under the supervision of the Forest Institute of the Academy of Sciences of the USSR. Soil moisture studies were begun by Roychenko (16). Because of certain considerations we selected other areas in the village of Aral and made our observations from February, 1949 to October, 1951.

The walnut forest (3) is located on the Arslanbob Plateau in the foothills of the Baubash-Ata Range. The relief is gently rolling. The plateau is deeply dissected and slopes to the southwest; it is bordered on the north by the high Baubash-Ata Range, and on the south, by the moderately high (2500-3000 m above sea level), main mountain elevation, opening toward the deep Arslanbob River valley. It reaches an absolute elevation of 1800-1900 m in the northeast. The relative elevation of individual ridges is 100-200 m. Because of its general slope toward the southwest, most of the slopes of the plateau are exposed to the west and southwest. Surface deposits are represented by loess.

The general climatic characteristics of the zone of walnut forests are given in the work of Alisov and Lupinovich (1). To determine the weather characteristics from 1949-1951 and the relationship between meteorological elements and soil moisture, 2 meteorological observation points were established at the station (10). The material at the Ak-Terek Gava meteorological station was also used.

Let us describe certain characteristics of weather conditions during the period of soil moisture studies. Table 1 gives the total precipitation at the Aral station and (for computation) those at the nearest meteorological station, Ak-Terek Gava.

As we can see from Table 1, the annual precipitation totals for 1949 and 1951 exceeded the long-period mean, and only in 1950 was the total less than this mean. As compared to the Ak-Terek Gava station, annual precipitation in the village of Aral was 80-90 mm less. This difference in the amount of precipitation is attributable to the difference in elevation between the village of Aral (1320 m) and the Ak-Terek Gava station (1748).

Precipitation distribution is very uneven during the year. Thus, in 1949, July was dry, in 1950, September, and in 1951, August and September. Precipitation is frequently of the shower type, the daily maximum at the forest station reaching 55.5 mm. The snow cover is even and does not drift because of the weak winds in the walnut forest zone. The mean long-period wind velocity, according to the data of the Ak-Terek Gava station, is 1.2 m sec. Precipitation is absorbed well by the soil and therefore it is evenly distributed at the surface.

During the years of observation, air temperature (mean annual in 1949 was 7.6°C, in 1950, 8.1°C, and in 1951, 8.3°C) was somewhat lower than the long-period mean of 9.1°C. This decrease in temperature was uniform throughout the year. If we consider that there was more precipitation during these years, with the exception of 1950, we will understand that this period was optimum as far as favorable moisture conditions are concerned. The temperature conditions at the forest station differed little from those at the meteorological station, whereby at a height of 2 m in the field the air temperature was 0.3°-0.4°C higher, and in the forest 0.1-0.5°C lower than at the same height at the Ak-Terek Gava meteorological station. In summer, the daily average air temperature was lower by 0.8°-1.8°C in the forest than in the field. The difference in the temperature regime in the field and in the forest was especially great in the air layer near the ground (Table 2) during the dry and hot summer months.

Data in Table 2 show that the temperature amplitudes were smaller in the forest than in the field. During the summer months the difference in the temperature of the air layer near the ground in the forest and in the field reached 22.0°C at individual observation periods.

The temperature conditions of the air layer

Table 1

Monthly and annual total precipitation, mm

Month	Long-period mean for the Ak-Terek- Gava station	1949		1950		1951	
		Ak-Terek- Gava	Aral	Ak-Terek- Gava	Aral	Ak-Terek- Gava	Aral
Jan.	70	57,8	62,0	107,9	107,1	88,6	78,6
Febr.	68	92,2	108,5	30,7	26,6	122,0	155,9
March	120	178,9	208,0	96,3	99,2	30,1	34,0
April	111	135,4	127,6	117,7	100,2	84,6	101,2
May	124	179,9	189,7	99,1	72,3	194,4	154,2
June	79	165,4	85,6	70,9	52,9	36,8	50,4
July	38	7,3	3,2	33,9	27,0	63,3	72,4
Aug.	31	165,0	48,7	33,8	19,4	4,6	0
Sept.	20	22,3	15,3	7,3	6,8	4,5	0
Oct.	79	49,6	42,4	102,3	91,8	200,3	115,8
Nov.	96	62,4	51,4	114,3	111,4	—	—
Dec.	81	15,8	12,5	32,7	41,4	—	—
Annual total	917	1132,0	949,9	846,9	756,1	829,2 ^a	762,5 ^a

^aTotal for 10 months.

Note: Comma represents decimal point.

Table 2

Mean monthly temperature of the air layer near the ground in degrees Centigrade for the station at the village of Aral (average for 3 years)

Point of observa- tion	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual average	Absolute	
														Max.	Min.
Forest	-6,4	-5,5	0,0	7,6	14,5	15,1	18,2	18,2	13,5	7,6	-0,7	-5,9	6,4	47,3	-24,3
Field	-6,5	-5,7	-0,1	8,1	16,6	20,0	23,1	22,6	15,5	7,8	-0,9	-6,5	7,9	>60,0	-27,3

Note: Comma represents decimal point.

near the ground in open old-plowed areas are unfavorable for walnut. The warming of the soil surface up to 60.0°C and more causes strong evaporation and the burning of the column of walnut plants.

The experimental areas in which soil moisture, microclimate, and vegetation were studied are located in the central part of a gentle southwestern slope with a grade of 6°. They are located in the village of Aral in the forest zone at an elevation of 1320 m above sea level in the center of a forest area. The areas were established in the forest and in an old-plowed field with a Persian walnut plantation sown in 1949.

The forest area consists of a pure 2-story walnut stand with undergrowth. The first story consists of 52 walnut trees per hectare of an average height of 22 m and an average stem diameter of 42 cm. Their predominant age is 80-90 years. Site quality is II/III. Crown enclosure is 0.5. The second story consists of walnut shoots, 72 clumps/ha, of an age of 10

years and of an average height of 12 m. In 1939 the area was subjected to selection cutting during which one-third of the stems was removed from the entire area of the village.

The underbrush is irregularly developed: well in clearings and poorly under enclosed crowns. It consists primarily of *Prunus sogdiana* Vass. (440 shrubs/ha) with an admixture of *Crataegus altaica* Lge. (64 shrubs/ha), and individuals of *Rosa corymbifera* Borkh., *Lonicera Altmani* Rgl., and *Cotoneaster multiflora* Bge.

The grass stand is thick. It is represented by three groups. 1. Short-stalk crowfoot, predominantly *Ranunculus baldschuanicus* Rgl., and *Brachypodium silvaticum* (Hud), and less *Aegopodium podagraria* L., *Allium winclerianum* Rgl., *Conioselinum larifolium* Rupr., and *Rumex crispus* L. 2. Short-stalk, girchovnikovo predominantly *Conioselinum larifolium* Rupr., and *Brac hypodium silvaticum* (Hud), and less *Bromus Benekeni* (Lge) Trimen., *Festuca gigantea* (L.) Will., *Ranunculus baldschuanicus* Rgl., etc. 3. Short-stalk goutweed, poor in

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Table 3

Amounts of non-readily available (physiologically unavailable) water in dark-brown, saturated forest soils of the village of Aral, mm of water

Soil	Thickness of soil layer, cm					
	0-50	0-100	0-150	0-200	0-250	0-300
Thick under walnut forest	109	204	284	348	406	477
Old-plowed shallow	76	146	214	275	328	398

Table 4

Minimum moisture capacity of dark-brown, saturated forest soils, % of volume

Thick under walnut forest				Shallow, old-plowed, Aral	
According to Letunov (12)		Aral			
Horizons and depth, cm	Moisture capacity	Horizons and depth, cm	Moisture capacity	Horizons and depth, cm	Moisture capacity
A_1' 0-5	54,5	A_0 0-1	56,1	A_{1-2} 0-10	48,5
5-10	52,4	A_1 2-17	46,7	10-20	30,4
10-15	43,8	A_2 18-30	47,4	20-30	34,1
A'' 20-30	46,9	AB 30-50	47,6	B_1 29-60	37,4
AB 45-55	38,5	B_1 50-83	40,1	B_2 61-90	36,9
B_1 65-75	36,3	B_2 84-140	38,9	C 91-300	36,9
B_2 90-100	27,4	C 140-300	39,7	—	—
Total, mm					
in 0-50	230	—	246	—	199
layer 0-100	394	—	438	—	373
0-150	—	—	629	—	560

Note: Comma represents decimal point.

species, concentrated in the deep shade of the walnut tree crowns. The grass consists of 3 stories. The first story reaches a height of 1.5-1.7 m.

The soil in the forest area is thick dark-brown, forest base-saturated soil (black-brown according to Gerasimov), developed on loess-like clay loam. It has the following structure. Profile 1, April 8, 1955.

A_0 0-2 cm. Loose litter, almost decayed, consisting of the remains of branches and leaves.

A_1 2-17 cm. Dark-brown clay loam of a nutty-blocky structure, dry, with a great number of roots, predominantly small. The transition is gradual.

A_2 17-30 cm. Dark-brown clay loam, with a nutty but less stable structure than the preceding horizon, damp. Many roots of varying diameters. The transition is gradual.

B_1 30-83 cm. Brown, clay loam, compact, damp. Contains a great number of white specks and various roots. The transition is gradual.

B_2 83-140 cm. Dark-yellow, damp, clay loam of a heterogeneous structure, darker spots alternate with light spots. There are

many roots and some pseudo-mycelium. The transition is gradual.

C 140-300 cm. Pale yellow, loess-like clay loam, very damp. Contains remains of land mollusks. The number of roots is smaller, but still quite large.

The area is characterized by a shallow temporary water table.

A second experimental area, covering 4.5 ha, was established in a clearing on the same southwestern slope at a distance of 150 m from the forest area to study the microclimate and soil moisture conditions of old plowed fields. In 1948 oats were sown in the clearing. In 1949 the area was left untouched and the predominating plant was *Melilotus officinalis* (L.) Desr. with an admixture of *Convolvulus arvensis* L. In the autumn small plots of 0.25 m² were cultivated in this area and walnut and accompanying shrubs were sown on them. In 1950 the predominating plant was *Hipericum perforatum* L. with a small admixture of *Artemisia absinthium* L. In this field the soil is shallow, dark-brown, base-saturated forest soil developed on loess-like clay loam.

Soil moisture was studied gravimetrically. Soil samples were taken twice a month 3 times every 10 cm to a depth of 190 cm. In addition to

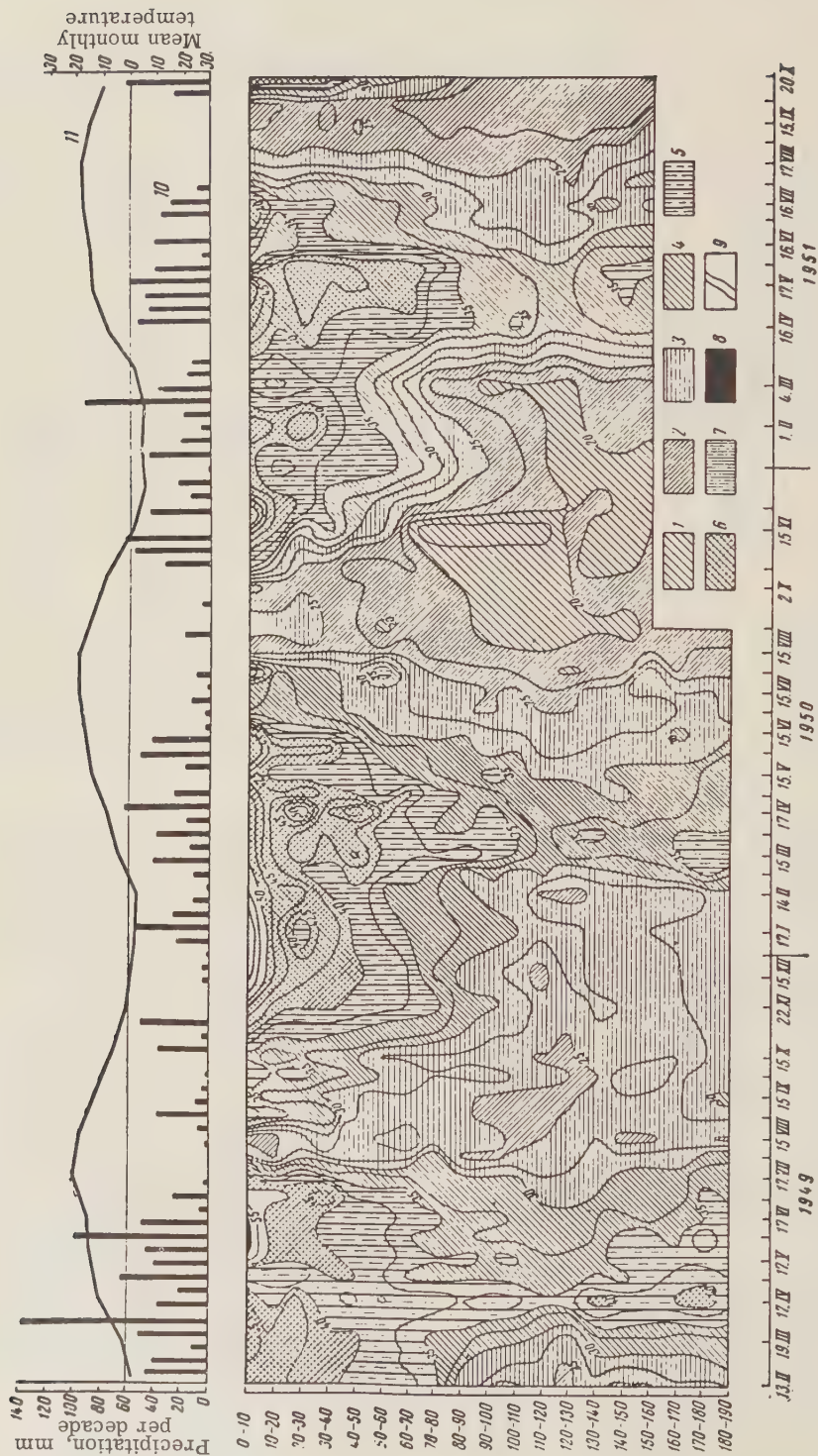


Fig. 1. — Moisture dynamics in thick dark-brown, forest base-saturated soil in a walnut forest, % of soil volume; precipitation distribution and monthly mean air temperatures.

Moisture: 1 - from 15%-20%; 2 - from 20%-25%; 3 - from 25%-30%; 4 - from 30%-35%; 5 - from 35%-40%; 6 - from 40%-50%; 7 - from 50%-60%; 8 - more than 60%; 9 - hydrochronoisopleths; 10 - precipitation distribution; 11 - mean monthly air temperatures.

moisture, the bulk density of the soil was determined by the Kachinskiy method (7), as well as its wilting moisture and the minimum moisture capacity in both experimental areas.

The bulk density varied along the soil profile from 1.12-1.30 in the A horizon of the thick dark-brown, forest base-saturated soil in the forest, and from 1.06-1.09 in the same horizon of the shallow old-plowed soil. The bulk density of the B horizon in both areas increases to 1.50, and then gradually decreases to reach 1.20-1.30 in the transitional horizon to the C horizon, and that becomes constant at 1.45 in the C horizon (loess).

The wilting moisture was determined by the biological method (2). It changed in the following manner along the profile: it was maximum (18.8%) in the upper layer from 0-20 cm, decreased gradually with depth and reached 6.5% at a depth of 2-2.5 m. Then it increased again with depth to reach 10-12%. It was at a maximum in the same horizons in thick dark-brown, base-saturated soils; wilting moisture was less in medium thick soils, and least in shallow soils.

The amounts of available and unavailable moisture were calculated on the basis of wilting moisture data. Table 3 gives the amounts of unavailable water in the dark-brown, base-saturated forest soils of the experimental areas.

As we can see from Table 3, the amounts of non-readily available water in thick soils are somewhat higher than in shallow soils, where by the major difference is found in the upper soil layer (0-100 cm).

The minimum moisture capacity of thick black-brown soils is very high. Table 4 gives its values for the soils of our areas in comparison with the data of Letunova (12). As we can see from these data, the minimum moisture capacity of virgin black-brown soils is considerably higher than that of shallow old-plowed soils. The difference in the layer from 0-15 cm deep is 69 mm.

Let us now examine the dynamics of moisture in thick, dark-brown, forest base-saturated soil in the walnut forest with myrobalan plum underbrush (Fig. 1).

The forest growing in the experimental area is one of the most productive types of walnut forests in Southern Kirgizia as far as the yield of wood and fruit is concerned. The only limiting factor for the growth of plants on dark-brown, forest base-saturated soils, extremely rich in nutrients, is moisture deficiency.

Soil moisture increases and begins to accumulate in the dark-brown, forest base-saturated soil during the rainy autumn periods in September-October. This is the end of the growing season, and, consequently, moisture losses from transpiration cease and moisture losses by evaporation from the soil surface decrease (in October the average daily temperature of the air layer near the ground decreases to 7.6°C).

In winter, moisture accumulates at the soil

surface in the form of snow cover. According to our data (10), its thickness in the village of Aral at an elevation of 1320 m varied from 55-128 cm in 1949-1951. In the village of Zindan at an elevation of 1900 m, snow cover depth reached 174 cm. Dark-brown soils do not freeze with such a thick snow cover and mild climate. Therefore moisture moves in winter downward along the soil profile from the horizons wetted in autumn into the dry lower horizons, and this downward flow of moisture is maintained in wet years to the end of July (1949), and to mid-June in dry years (1950).

Maximum annual precipitation occurs in spring during the snow melting period (March-April). The growing period just begins, physical evaporation is still small (the average monthly temperature of the air layer near the ground is 0°C in March and 7.6°C in April), and soil moisture reaches its maximum during this period. The good moisture absorption by the soil is attributable to the presence of a loose litter and the high water-holding capacity of these soils.

The maximum moisture content in spring is found in the A₁ horizon. Moisture losses increase by the end of spring in spite of the considerable amount of precipitation during this period (190 mm in May, 1949 and 154 mm in May, 1951). Vegetation develops rapidly, using a large amount of moisture on transpiration. As the average monthly temperature of the air layer near the ground increases to 14.5°C in May, moisture evaporation from the soil surface also increases.

The soil continues to dry out throughout the summer. Summer precipitation does not penetrate deeper than 50 cm and is rapidly used by the vegetation or evaporates directly from the surface of plants and from the soil (the soil warms to 47°C in summer, even in the forest). Water is used more or less evenly along the soil profile in the forest.

During the spring periods of 1949, 1950, and 1951 the soil was wetted thoroughly to the depth of observation. This depth is not sufficient to determine definitely the water regime of dark-brown soils. However, judging by the fact that maximum desiccation reaches a depth of only 150-170 cm, we may rightly conclude that there is no constantly dry layer under the wetted layer. Consequently, according to the classification of Rode (17), the water regime is of the leaching type. However, the short duration of our observations does not permit us to consider this conclusion as being proved, since there may be years in the long-period cycle of climatic variations with such a small amount of precipitation that it would not be sufficient to wet the soil through even in spring.

Table 5 gives the moisture contents by layers, the amounts of available moisture, and moisture expectancy.

The maximum moisture contents in the 0-150 cm layer of the soil are created during the second half of March and in April and are retained to mid-June. Then they rapidly become depleted, reaching a minimum in September-October. During wet years the amounts of

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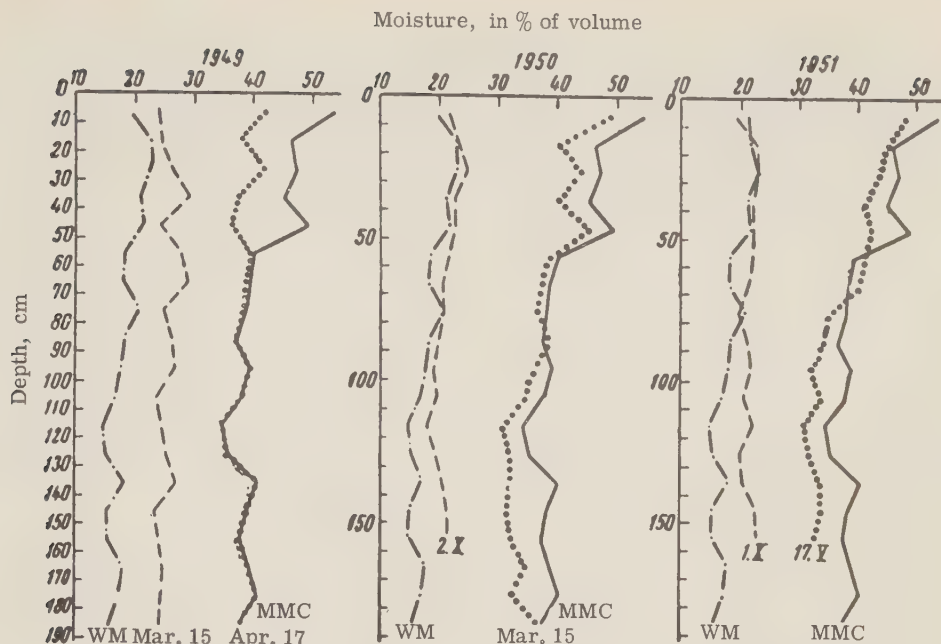


Fig. 2 - Moisture dynamics along the profile of thick dark-brown, base-saturated soil in the forest at the time of maximum and minimum moisture reserves. WM—wilting moisture, MMC—minimum (field) moisture capacity.

Table 6

Temperature (0°C) of the air layer near the ground and of the soil, August 15, 1950

Depth, cm	Forest				Field			
	Hour							
	1	7	13	19	1	7	13	19
0	15.0	16.5	28.4	20.0	10.0	12.3	55.0	21.5
5	16.5	14.5	17.7	19.0	21.2	17.0	33.0	31.5

available moisture last throughout the year, while in dry years they become depleted. During a dry autumn the moisture of certain soil layers may drop below wilting moisture.

In spite of the large amount of precipitation and the high moisture-holding capacity of these soils, the moisture contents in them never reach values corresponding to the minimum moisture capacity. This is attributable to the fact that while the moisture contents continue to grow in the lower soil layers, the upper layers begin to dry out. About three-quarters of the spring moisture contents are used by autumn.

From the foregoing material it follows that even during the wet year of 1949 the available moisture of the upper soil horizons in the walnut forests was used by August, and the moisture in the layer from 10-20 cm dropped below the wilting moisture contents. The total supply of available moisture in the layer from 0-50 cm was 20 mm.

In the dry year of 1950 there was practically no moisture available to plants (6 mm) in the layer from 0-50 cm in August, while the moisture of the surface horizons dropped 1%-6% below the wilting moisture content. The moisture content in the layer from 50-100 cm in August was 53 mm during a wet year and 23 mm during a dry year, while in the layer from 100-150 cm the moisture content increased to 83 mm during a wet year and to 54 mm during a dry year. A sharp decrease in available moisture during wet years occurs in July, while during dry years it occurs a month earlier.

Thus, plants which have their root systems in the upper meter of the soil in the walnut forest find themselves under difficult moisture supply conditions in dry years by the second half of June. According to the data of Krasil'nikov (8), the fine roots of mature Persian walnut trees form a three-story layer: 0-15 cm, 100-120 cm, and 300-350 cm. Therefore, the walnut tree can draw moisture from the deep soil horizons when the upper meter of soil is dry. The foregoing soil moisture conditions during

Table 7

Dynamics of moisture contents in shallow, old-plowed forest base-saturated soil

Depth, cm	Contents (mm) corresponding to				Contents by periods, mm																						
	Minimum moisture capacity	Willing moisture	Range of moisture	active moisture	1949				1950								1951										
					Feb. 13	Apr. 17	May 3	July 1	Aug. 15	Sept. 1	Oct. 15	Oct. 22	Mar. 2	Mar. 15	Apr. 30	June 1	July 1	Sept. 2	Oct. 2	Nov. 15	Dec. 1	Apr. 16	July 1	Aug. 2	Oct. 1		
Total moisture contents, mm																											
0-50	199	76	123	186	156	162	127	84	91	94	153	182	171	157	160	91	75	65	166	155	146	121	62	70			
50-100	175	70	105	158	177	173	156	102	100	107	124	149	167	164	157	119	86	79	139	147	143	148	76	91			
100-150	186	68	118	142	182	161	156	118	126	116	126	139	163	159	150	137	89	106	105	122	142	155	93	117			
0-150	560	214	346	486	515	496	439	304	317	317	403	470	501	480	467	347	250	250	410	424	431	424	231	278			
Contents of available moisture, mm																											
0-50	—	—	—	110	80	86	51	8	15	18	77	106	95	81	84	15	—1	—11	90	79	70	45	—14	—6			
50-100	—	—	—	88	107	103	86	32	30	37	54	79	97	94	87	49	16	9	69	77	73	78	6	21			
100-150	—	—	—	74	114	93	88	50	58	48	58	71	95	91	82	69	21	38	37	54	74	87	25	49			
0-150	—	—	—	272	301	282	225	90	103	103	189	256	287	266	253	133	36	36	196	210	217	210	17	64			
Degree of moisture availability, %																											
0-50	—	—	—	90	65	70	41	6	12	15	62	86	77	65	68	12	—1	—9	73	64	57	36	—11	—5			
50-100	—	—	—	84	102	98	82	30	28	35	51	75	92	90	83	46	15	8	65	73	70	74	5	20			
100-150	—	—	—	62	96	78	74	42	49	40	49	60	80	77	70	58	18	32	31	46	62	73	21	41			
0-150	—	—	—	78	87	82	65	26	30	30	54	74	83	77	73	38	10	40	56	61	63	61	5	18			

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Table 8

Moisture contents, moisture losses, and precipitation, mm of water

Year	Maximum				Minimum				Use during given period				Precipitation ^a
	0-50	50-100	100-150	0-150	0-50	50-100	100-150	0-150	0-50	50-100	100-150	0-150	
	Thick, dark-brown, forest base-saturated soil under walnut forest												
1949	April 17				March 15								
	199	195	191	585	130	136	127	393	69	59	64	192	373
1950	March 15				Sept. 2								
	221	182	164	567	127	101	91	319	94	81	73	248	319
1951	May 17				Oct. 1								
	220	186	168	574	112	108	108	328	108	78	60	246	193
Average	213	188	174	575	123	115	108	347	90	73	66	229	295
	Shallow dark-br ^o wn, old-plowed forest base-saturated soil												
1949	April 17				March 15								
	156	177	182	515	84	102	118	304	72	75	64	211	373
1950	April 17				Sept. 2								
	176	178	166	520	75	86	89	250	101	92	77	270	233
1951	May 17				Aug. 1								
	166	174	165	505	62	76	93	231	104	98	72	274	193
Average	166	176	171	513	74	88	100	262	92	88	71	251	264

^aPrecipitation at the moment of soil moisture determination (from the maximum to the minimum).

dry years are extremely unfavorable for natural seedlings, one- and two-year old Persian walnut trees, which have their root systems at a depth from 0-100 cm. If we consider that the recorded total precipitation during certain years was 638 mm (1944) as compared to 845 mm in the "dry" year of 1950 during which we made our observations, we will understand that there is a possibility of the loss of natural seedlings and walnut plantings from a deficiency of soil moisture during such years.

Since it was worthwhile to restore walnut forests by planting old-plow fields, splitting up the continuity of the forest massive, it was necessary to study the moisture regime of these lands also (Fig. 2).

The process of moisture accumulation in shallow old-plowed soil is generally the same as in the thick, dark-brown, forest base-saturated soil in virgin areas: moisture accumulates in autumn, is kept at the soil surface in the form of snow in winter, and reaches its maximum after the melting of snow and during precipitation in spring.

Old-plowed soil begins to dry earlier than virgin soil in the forest. The process of drying is more intense, and the moisture content of the upper horizon drops below wilting moisture content even during wet years. The soil dries unevenly along the profile, the upper horizons (0-30 cm) drying most intensely.

Desiccation embraces the layer from 0-150 cm. At greater depths soil moisture is higher in the clearings than in the forest. This drying of the upper horizons of old-plowed soil is associated first of all with the location of the root system of grass vegetation in the layer from 0-50 cm (15), and also with the fact that the surface of the soil is not protected by trees and therefore warms up greatly.

The soil surface in the clearing warms up to 55.0°C so that evaporation is very intense (Table 6).

Table 7 gives the moisture contents by layers, the amounts of available moisture, and the degree of moisture availability to plants in the shallow old-plowed soil. We can see from the table that the moisture contents in the shallow old-plowed soil are lower than in the virgin soil. Thus, in the wet year of 1949 the moisture content in the layer from 0-150 cm was 515 mm, which is 70 mm less than in virgin soil. The causes for the lower moisture contents in the old-plowed soil are apparently the poorer physical properties of the soil and also surface runoff; moreover, old-plowed soil loses moisture more intensively. Thus, for instance, even in the wet year of 1949 the contents of available moisture in the layer from 0-50 cm were exhausted by June. In the drier year of 1950 the moisture content in this layer dropped below wilting moisture in September. The drying of the upper horizons of old-plowed lands to values

close to the wilting moisture in 1950 was apparently the cause of the dying of a considerable part of 2-year old Persian walnut trees both in the village of Aral as in other forest areas, especially in plantings with a cover crop of oat, wheat, and barley.

Thus, there is a clear difference between the moisture regime of thick dark-brown, forest base-saturated soil under the walnut forest and that of the shallow dark-brown, old-plowed forest base-saturated soil, which consists in that the latter dries more in the upper horizons but contains more moisture at depth (starting with a depth of 100 cm).

The reason for this difference is apparently strong evaporation from the surface of the field which is less protected by vegetation from the intense insolation in the mountains of Central Asia.

A better picture of the difference between the water regime of thick, dark-brown, forest base-saturated soil in the walnut forest and that of shallow, dark-brown, old-plowed forest base-saturated soils is obtained from Table 8, which shows that the maximum and minimum moisture contents in the same horizons in the thick, dark-brown soil in the forest are higher than in the shallow old-plowed soil. The moisture loss during the growing period in the layer from 0-50 cm is the same everywhere, but the thicker layers, the 0-100 cm layer for instance, in the old-plowed soil lose more moisture than in the forest. The difference in moisture losses between the 2 foregoing soils increases in the 0-150 cm, averaging 20 mm in 3 years.

Conclusions

1. The common features of dark-brown, forest base-saturated soils are the increase in moisture contents during the autumn-winter-spring period, a high moisture content at the end of spring, and the gradual decrease of the summer moisture content toward autumn. Moisture begins to accumulate again in the soil in autumn and lasts until winter. In winter the moisture content does not increase in the upper 2 m of the dark-brown, forest base-saturated soils, the moisture only moves from the upper into the lower horizons.

2. The moisture regime of dark-brown soils in the forest is of the leaching type, according to 3 years of observation, two of which having had increased precipitation.

3. The maximum and minimum soil moisture contents in the forest are higher than in old-plowed soil, while the moisture losses in the forest are lower.

4. Because of the differing moisture regimes of virgin soil in the forest and old-plowed soil, agricultural practices for the growing of Persian walnuts on these soils must be different. The method of soil tillage by areas followed by shallow cultivation and mulching to provide plants with moisture even in dry years is very suitable for virgin dark-brown, forest base-saturated soils.

During dry years the moisture content of the upper layers of old-plowed soils remains below the wilting for a long time. Therefore, more effective results in the restoration of forests on old-plowed lands will be obtained by strip or complete soil tillage accompanied by mulching or irrigation during the first years of growth of Persian walnut plantings.

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NATURE OF HUMUS IN SOILS OF THE TROPICS AND HUMID SUBTROPICS

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Lateritic and red earth soils are widespread in the tropics and subtropics, covering (according to L. I. Prosalov) 19% of the area of all the continents. In spite of their wide distribution these soils and, in particular, the nature and properties of their humic substances have not been studied sufficiently to this day, even though a number of papers on this problem have been published recently (1, 2, 3, 5, 7).

We investigated the nature of humus in the soil of the Yunnan Province in the Chinese People's Republic, located in the tropical and subtropical zones, and the adjoining northern portion of the Democratic Republic of Vietnam (tropical zone). For comparison we took the red earth from Chakva (USSR).¹

The physiographic conditions of Yunnan Province are unusually complicated. They are characterized by the prevalence of a subtropical and tropical monsoon climate with a pronounced summer rainy season, a dry winter, and a pronounced demarcation between the wet and dry seasons. In the Kunming region of this province, where the soil samples were collected, the temperature of the coldest month is above 9°C, while that of the hottest month exceeds 20°C; the mean annual temperature is about 16°C. There is practically no frost. The mean annual precipitation amount varies between 1000 and 1200 mm.

Northern Vietnam, where the other series of samples was taken, is located in the northeastern part of the Indochina Peninsula. As far as climate is concerned, Northern Vietnam is somewhat similar to Yunnan, however it is characterized by higher temperatures and more ample precipitation. Because of the lack of climatic data for the area where the samples were taken, we used data for Hanoi. Here the mean annual temperature is 23.5°C, the mean temperature of the coldest month is

16.3°C, and that of the hottest month, 28.9°C. The annual precipitation is 1753.1 mm, whereby four-fifths of the precipitation from May to October is brought by southwesterly summer monsoons.

The place in the USSR from which the samples of red earth were taken — Chakva — is located in Georgia, where the mean annual temperature is 13.8°C, the mean temperature of the coldest month is 5.5°C, and that of the hottest month, 22.3°C. The annual amount of precipitation is 2427 mm.

The parent materials of the soils studied are varied. The red earths and lateritic soils of Yunnan Province develop on gneiss, dolomite, and limestone. The soils of Northern Vietnam develop on basalt, granite, and gneiss. As far as the red earths of the USSR are concerned, they develop on andesite-basalt.

All the lateritic soils and red earths studied (except for the red earth on dolomite from Kunming, which is covered by grasses) are occupied by forests with very enclosed crowns. Figs, evergreen oaks, and lianas predominate in the composition of vegetation of Yunnan Province; the underbrush is represented by bamboo, ferns, and various shrubs. In Northern Vietnam the soils are covered by an evergreen tropical forest with bamboo, while the underbrush consists of ferns, ginger plants, and grasses. The vegetation of the red earth in Chakva consists primarily of laurelcherry and lianas, while ferns predominate among the ground vegetation.

The soils studied have an acid reaction; the pH of the salt extract is in most cases about 4.0; only in the red earth on dolomite and in the lateritic soil on limestone from Kunming is the pH of the salt extract close to neutral. The adsorption capacity for cations of the red earths of the Chinese People's Republic and the soils of the Democratic Republic of Vietnam is low, from 3-13 meq/100 g of soil. The adsorption capacity of lateritic soil on limestone from Kunming reaches 52.14 meq/100 g of soil. The majority of the adsorbed cations in this soil, as well as in the red earth on dolomite from Kunming, consists of Ca and Mg, which gives us the right to consider them as special subgroups of subtropical soils (13).

We determined the total amount of humus

¹ Soil samples from Yunnan were sent us by Prof. Li Chen-kweem and the soil scientist Chou Kuo-ch'u (Soil Institute, Academy of Sciences of China); V. M. Fridland (Soil Institute, Academy of Sciences, USSR) kindly gave us soil samples from the Democratic Republic of Vietnam; and the soil from Chakva was obtained from B. P. Gradusov (Soil Institute, Academy of Sciences, USSR).

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and nitrogen in these soils, as well as the composition of humus. To characterize the nature of humic substances we determined their elementary composition, optical density, and relation to electrolytes. Moreover, by means of paper chromatography we studied the amino-acid composition of humic and fulvic acids.²

The Content of Humus and Nitrogen, and the

²We used the methods adopted in the laboratory of soil biochemistry and biology of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR; these methods were described in a number of articles (1, 5, 6, 7).

C:N in the Soils. Organic carbon was determined by the Tyurin method, and nitrogen by the Kjeldahl method. Our data (Table 1) show that the humus content in the upper horizons of the red earths from China varies from 2.65%-3.28%. We found a somewhat higher humus content in the lateritic soils of China and Vietnam, which varied from 5.03%-10.90% in the upper mineral horizons of the soils. The nitrogen content in the soils studied is in direct relation to the humus content and varies from 0.29%-0.58% in lateritic soils and from 0.15%-0.37% in the red earth soils. The C:N ratio in red earths and lateritic soils varies from 10.1-15.9. The same C:N ratio was found by a number of authors for

Table 1

Humus and nitrogen content in red earths and lateritic soils

Profile No.	Soil	Depth, cm	Total organic C, % of soil weight	Humus (C x 1.724)	Total N, % of soil weight	C : N
1	Red earth on dolomite, Kunming, Yunnan Province, Chinese People's Rep.	0-5	1,90	3,28	0,15	12,7
2	Red earth on gneiss, Hekoy, Yunnan Province, CPR	0-10 50-60	1,50 0,55	2,65 0,95	0,15 0,06	10,3 9,2
3	Lateritic soil on limestone, Kunming, Yunnan Province, CPR	0-10	6,32	10,90	0,58	10,9
463	Humic-lateritic mountain soil on sandstone, Kunming, Yunnan Province, CPR	0-10 10-14 16-26	18,32 1,70 1,89	31,58 2,93 3,26	0,72 0,07 0,11	25,4 24,3 17,2
17	Lateritic soil on basalt, Nge Ang Province, Vietnam	0-10 10-20 20-30 40-50 60-70 100-120	2,92 1,75 1,59 1,16 0,98 0,75	5,03 3,02 2,74 2,00 1,67 1,29	0,29 0,17 0,15 0,10 0,10 0,08	10,1 10,3 10,6 11,6 9,8 9,4
356	Lateritic-humic mountain soil on gneiss, Tan Meo National District, Vietnam	1-6 12-22 28-34 40-50 70-80	13,30 6,32 3,00 0,97 0,11	22,93 10,90 5,17 1,67 0,19	0,89 0,45 0,20 0,07 0,01	14,9 14,0 15,0 13,9 11,0
171	Humic-lateritic mountain soil on granite, Dienbienphu, Vietnam	1-6 6-10 12-16 18-22 24-29 31-41 45-55	5,40 3,83 2,31 1,59 1,28 1,09 0,90	9,31 6,60 3,98 2,74 2,21 1,88 1,55	0,34 0,22 0,15 0,12 0,10 0,08 0,08	15,9 17,4 15,4 13,3 12,8 13,6 11,3
155	Red earth on andesite-basalt, Chakva, USSR	0-20 40-50 100-110	5,36 1,25 0,16	9,24 2,16 0,28	0,37 0,07 —	14,5 17,9 —

Note: Comma represents decimal point.

the red earth from the USSR (2, 5, 9, 11). The widest C:N ratio (25.4) in the upper horizon of humic-lateritic mountain soil (Profile 463) is attributable to the admixture of semi-decomposed remains, not readily separated during the preparation of soil for analysis. However, a similarly wide C:N ratio in the comparatively slightly humic layer from 10-14 cm indicates that the nitrogen content of humus in the given soil is generally low. The C:N ratio in the red earths from China is narrower than that in the red earth from Chakva, especially in the lower horizons; the cause of this is not clear to us yet.

Composition of Soil Humus. The composition of soil humus was determined according to the Tyurin method, slightly modified in the laboratory of soil biochemistry and biology of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR. According to this method we determined the following groups of substances:

- 1) Organic substances soluble in a 1:1 alcohol-benzene mixture.
- 2) Organic substances extracted during the treatment of the soil with 0.05 N H_2SO_4 (during the decalcification of the soil).
- 3) Humic substances (humic and fulvic acids), extracted from the soil (after decalcification) by means of repeated treatment with 0.1 N NaOH.
- 4) Humic substances (humic and fulvic acids) were further extracted by an alternate treatment of the soil with 0.1 N H_2SO_4 and 0.1 N NaOH.

The groups of humic and fulvic acids in alkaline extracts were separated in both cases (3 and 4) by acidification and careful warming of the extracts for 1 hour; the humic acids settle in the form of a gel, while the fulvic acids remain in the acid solution.

- 5) The total amount of carbon and nitrogen was determined in the soil residue.
- 6) The group of mobile humic acids — free and firmly bound with the mineral portion of the soil, were determined in a special, non-decalcified soil sample by means of 0.1 N NaOH.

A glance at the data on the composition of humus (Table 2) shows that substances extracted by the alcohol-benzene mixture comprise a very small amount not exceeding 3%-10% of the total content of carbon in the organic substances in the soil. We could not find any pattern in the content of this group of substances in the soils. We only noticed a certain tendency of the amount of organic substances, extracted during soil decalcification, to increase in the lower horizons; this phenomenon is attributable to the transport of the substances from the upper horizons.

As far as the group of humic substances proper is concerned, fulvic acids predominate over humic acids in red earths and lateritic soils; correspondingly, the ratio of humic:fulvic acids varies from 0.40 to 0.67. Only in 2 cases — in lateritic soil on limestone from Yunnan

and the lateritic-humic mountain soil on granite (Profile 171) was this value close to unity. As compared to the other soils studied, the lateritic soil on basalt from Vietnam (Profile 17) has the least amount of humic acids, comprising only 6.2% of the total carbon, and the highest amount of fulvic acids (34.7% of total carbon), as a result of which the ratio between the C of humic acids and the C of fulvic acids is only 0.18 in this soil. The ratio between the C of humic acids and the C of fulvic acids in the red earths of China is of the same order of magnitude as that in the red earth from Chakva.

The high content of organic carbon in the soil residue after the extraction of both groups (I and II) of humic substances is characteristic; it amounts to 40%, and in certain soils to 50% of the total carbon in the soils. This indicates that in the soils studied, which are characterized by a fine texture, a considerable part of the humic substances is closely associated with their mineral portion. The only exception is the lateritic-humic mountain soil on gneiss from Vietnam (Profile 356), where the amount of carbon in the residue is 31.8% in the layer from 12-22 cm and 37.1% in the layer from 40-50 cm of the total carbon content. This is attributable to the coarser texture of this soil; according to the data of Fridland (11), its physical clay content (<0.01 mm in diameter) is only about 30%.

The data in Table 2 show that the C:N ratio in the soil residue after the extraction of humic substances with alkali hardly differs from that in the initial soils. This once more substantiates the belief that nitrogen is one of the integral elements of humic substances in soils.

Let us note that the amount of mobile humic substances extracted by only one treatment of the soil with 0.1 N NaOH reaches 70%-100% of the total amount of humic acids extracted by the repeated treatment of decalcified soil with the same solution. The high relative content of mobile humic acids in the soils studied is attributable to the fact that both in the red earths and lateritic soils, as well as in podzolic soils, a large portion of humic acids is free or is loosely bound with the mineral elements of the soil. The only exception is the lateritic soil on limestone from Kunming where this group of humic acids comprises only about 33% of their total amount. The reason for this is apparently the high exchange capacity of the given soil and the predominance of Ca and Mg in it, to which, apparently, a considerable part of the humic acids is bound in more stable forms.

Nature and Properties of Humic Acids in the Soils studied. It is shown by a number of investigators (5, 10) that excessive moisture and the acid reaction of soils have a considerable influence on the formation of humic acids, in particular, by interfering with the polymerization and condensation of humic acids. A similar phenomenon is found in red earths, where, as in podzolic soils, these acids remain in the state of "chemical youth." This is confirmed by the results of our investigations.

In humic acid preparations, extracted after the decalcification of soil, we determined the coagulation (precipitation) threshold and optical

Table 2

Humus composition of red earths and lateritic soils in % of total organic carbon in the initial soil

Profile No.	Soil	Depth, cm	Total organic C, % of soil weight	C from the alcohol-benzene extract	C extracted during soil decalcification	C of humic acids				C of fulvic acids			C in soil residue	Total	C fulvic acids	Total N in the soil residue, % of init. soil	C:N in the soil residue	C in mobile humic acids	
						by groups												% of total C in init. soil	% of C in humic acids
						I		II		I	II								
						I	II	I	II										
1	Red earth on dolomite, Chinese People's Rep. (CPR)	0-5	1,90 100	4,2	3,2	10,5	4,8	15,3	20,0	2,6	22,6	51,1	96,4	0,67	0,08	12,1	7,9	51,7	
2	Red earth on gneiss, CPR	0-10	1,54 100	4,6	2,6	9,7	2,6	12,3	27,9	2,6	30,5	43,5	93,5	0,40	0,07	9,6	9,7	79,0	
		50-60	0,55 100	5,5	7,3	Traces				25,5	1,8	27,3	52,7	92,8	—	0,04	7,3	—	
3	Lateritic soil on limestone, CPR	0-10	6,32 100	3,8	3,0	14,1	8,5	22,6	18,8	4,5	23,3	40,7	93,4	0,97	0,26	9,9	7,6	32,9	
463	Humic-lateritic mountain soil on sandstone, CPR	10-14	1,70 100	11,2	3,5	8,8	2,9	11,7	16,5	1,2	17,7	52,9	97,0	0,67	0,04	22,5	8,8	75,0	
17	Lateritic soil on basalt, Vietnam	0-20	2,25 100	3,1	4,0	5,3	0,9	6,2	31,1	3,6	34,7	43,1	91,1	0,18	0,10	9,7	6,7	100	
356	Lateritic-humic mountain soil on gneiss, Vietnam	12-22	6,32 100	5,2	6,0	13,8	4,1	17,9	29,3	2,4	31,7	31,8	92,6	0,57	0,13	15,5	18,7	100	
		40-50	0,97 100	4,1	13,4	7,2	2,1	9,3	27,8	2,1	29,9	37,1	93,8	0,31	0,05	7,2	—	—	
171	Humic-lateritic mountain soil on granite, Vietnam	1-6 12-16	5,40 100 2,31 100	2,4 3,9	2,2 3,5	16,9 13,9	3,2 3,9	20,1 17,8	19,8 28,1	1,9 3,5	21,7 31,6	53,7 41,6	100 98,4	0,92 0,56	0,14 0,06	20,7 16,0	14,3 13,0	71,3 73,2	
155	Red earth on andesite-basalt, USSR	0-20 40-50	5,36 100 1,25 100	3,7 4,0	4,9 12,0	12,6 2,4	1,5 0,8	14,1 3,2	20,0 22,4	1,7 1,6	21,7 24,0	48,5 55,2	92,9 98,4	0,66 0,13	0,17 0,04	15,3 17,3	14,1 4,1	100 100	

Note: Comma represents decimal point.

Table 3

Coagulation threshold of sodium humates in red earths and lateritic soils

Pro- file No.	Soil	Depth, cm	Beginning of coagulation CaCl ₂ , meq/ liter of humate	Complete coagulation	
				Time, hr.	CaCl ₂ , meq/ liter of humate
1	Red earth on dolomite, Chinese People's Republic (CPR)	0—5	9	2 4	40 25
2	Red earth on gneiss, CPR	0—10	7	2 4	25 20
3	Lateritic soil on limestone, CPR	0—10	8	2 4	>40 17
463	Humic-lateritic mountain soil on sandstone, CPR	10—14	7	2 4	35 15
17	Lateritic soil on basalt, Vietnam	0—20	15	2 4	>40 40
356	Lateritic-humic soil on gneiss, Vietnam	12—22	10	2 4	40 30
		40—50	>40	2 4	
155	Red earth on andesite-basalt, USSR	0—20	20	2 4	>40 40
		40—50	12	2 4	25 25

density. The determinations were made in Na humate solutions, having equal carbon content (0.136 g of carbon in 1 liter of solution), and a reaction close to neutral. The thickness of the layer of solution in the spectrophotometer cells was 1 cm. The results of the determinations are given in Table 3 and in Figure 1. As we can see from Figure 1, the extinction coefficient, E, (optical density) in humic acids is generally low, varying between 1.3 and 1.7. By comparing these values with the corresponding values for humic acids of other soils (7) we can see that the optical density of humic acids in the red earths and lateritic soils of China and Vietnam corresponds to that of humic acids in the red earth and sod-podzolic soil from the USSR. We could not determine any pattern in the fluctuations of E for the individual soils studied. The low extinction coefficients permit us to assume that the degree of condensation of the aromatic series of humic acids in the red earths and lateritic soils studied is low.

This conclusion is confirmed by the results of determinations of the coagulation threshold of humic acids (Table 3). The data point to the high dispersion of humic acids; coagulation (and then only partial) takes place only when large amounts of electrolyte (CaCl₂) are added.

Elementary Composition of Humic and Fulvic Acids. We determined (by micro-method) the elementary composition of humic and fulvic acids from red earth and lateritic soils of China. The compounds were prepared using methods adopted by the laboratory of soil biochemistry and biology of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR (7). Data (Table 4) indicate that the carbon content in the humic acids is 57.77% and 58.65%. The low C:H ratio, amounting to 10.9 in the humic acid of the red earth and to 12.0 in the lateritic soil, points to the low degree of condensation of the aromatic nucleus, and this conclusion agrees with the foregoing optical density indices.

The carbon content of the fulvic acids in the same soils is 40.92% and 44.99%, respectively. In comparing data for the elementary composition of humic and fulvic acids in the red earth and in the lateritic soil with those of humic acids in other soils we can see that they are closest to the same acids in sod-podzolic soils.

Adsorption Capacity of Humic Acids in the Soils. We determined the exchange capacity by the Kukharensko method by infusing samples of humic acids with a 0.5 N solution of calcium acetate (8) having a pH of 6.8-7.0. The

HUMUS IN TROPIC SOILS

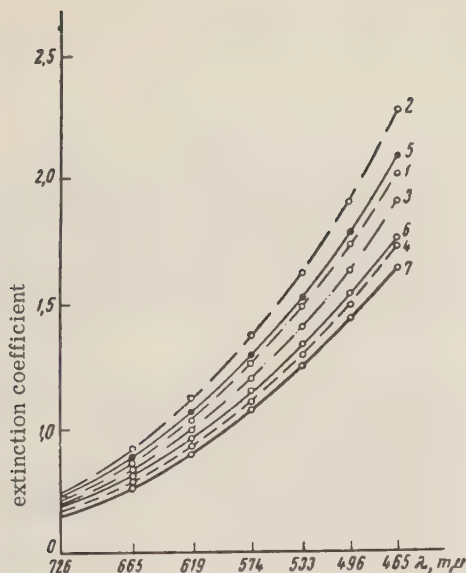


Fig. 1. - Optical density of humic acids.

1 - red earth on dolomite, Chinese People's Republic CPR; 2 - red earth on gneiss CPR; 3 - lateritic soil on limestone, CPR; 4 - humic-lateritic mountain soil on sandstone, CPR; 5 - lateritic soil on basalt, Vietnam; 6 - lateritic-humic mountain soil on gneiss, Vietnam; 7 - red earth on andesite-basalt, USSR.

adsorption capacity of humic acid from red earth (Table 4) was 272.8 meq/100 g of absolutely dry, ash-free substance. A somewhat

higher adsorption capacity was found of the humic acid in lateritic soil - 355.5 meq. In both cases these values are close to the corresponding values of humic acids in podzolic soil.

As a whole, the results of our study of the nature of humus indicate that the conditions of formation of the red earths and lateritic soils of the tropics and subtropics promote the formation of humic substances of the fulvic acid type, the amount of which exceeds that of humic acids. Judging by their elementary composition, optical density, and relation to electrolytes, the humic acids of the soils studied retain their "chemical youth." A considerable part of them is unstably bound with the mineral elements of the soil and is possibly bound to a certain degree with the mobile forms of R_2O_3 .

We were not able to determine the influence of various parent materials on the nature of humus; this, apparently, is attributable to the profound changes of the parent material during soil formation. Therefore the main factor determining the nature of humus in the soils studied by us is the bioclimatic factor.

Amino-Acid Composition of Humic and Fulvic Acids. To determine the amino-acid composition of humic substances we subjected them to hydrolysis with 6 N HCl for 20 hr., then, after correspondingly preparing the hydrolyzates (6), we made the determination by partition paper chromatography. We found 11 amino-acids in the humic and fulvic acids from the red earth and lateritic soil from Yunnan: histidine, arginine, aspartic and glutamic acids, glycocoll, threonine, alanine, proline, valine, phenylalanine, and leucine; in addition 2 unknown amino-acids were found on the chromatograms. There was no substantial difference in the amino-acid composition of the various

Table 4
Elementary composition in % of absolutely dry, ash-free matter, and exchange adsorption capacity of humic substances in various soils

Soil	Compounds	C	H	O	N	C:H	C:N	O:H	Exchange capacity, meq/100 g of matter	Ash, %	Author
Red earth on dolomite, CPR	h. a. ^a	57,77	5,33	32,89	4,01	10,9	14,5	6,2	272,3	12,34	Our data
	f. a.	40,92	4,33	52,14	2,61	9,5	15,7	12,1	—	7,53	
Lateritic soil on limestone, CPR	h. a.	58,65	4,88	32,35	4,12	12,0	14,3	6,6	355,5	4,22	"
	f. a.	44,99	4,67	47,29	3,05	9,6	14,5	10,0	—	6,88	
Red earth, USSR	h. a.	59,65	4,37	31,54	4,44	13,6	13,4	7,2	—	—	Kononova
	f. a.	49,82	3,35	44,33	2,50	14,9	19,9	13,2	—	—	
Normal chernozem, USSR	h. a.	62,13	2,91	31,38	3,58	21,4	17,4	10,8	—	—	"
	f. a.	44,84	3,45	49,36	2,35	13,0	19,1	14,3	—	—	
Sod-podzolic soil, USSR	h. a.	57,63	5,23	32,52	4,81	11,0	12,0	6,2	—	—	"
	f. a.	46,23	5,05	44,60	4,12	9,2	11,2	8,8	—	—	
Strongly podzolic soil, USSR	h. a.	58,11	5,37	32,00	4,52	10,8	12,9	6,0	—	—	"

h. a. - humic acids, f. a. - fulvic acids

Note: Comma represents decimal point.

samples; this substantiates the view of Kononova and Aleksandrov (6) that humic and fulvic acids form in a similar way.

Conclusions

1. The lateritic soils of the Chinese People's Republic and the Democratic Republic of Vietnam have a higher humus content than the red earths of Yunnan Province.

2. The nitrogen content in the foregoing soils is directly dependent on the humus content; as compared to other soil groups, the humus of tropical and subtropical soils is poor in nitrogen, which is shown by their wide C:N ratio.

3. Fulvic acids predominate in the humus of the soils studied: the ratio between the C of humic acids and the C of fulvic acids is <1. The humic acids are very mobile; a single treatment of the soil with 0.1 N NaOH extracts 70%-100% of the total humic acids separated by a prolonged treatment of decalcified soil with an alkaline solution. The high content of organic carbon in the residual soil is characteristic, which reaches 50% of its total content in certain cases. This is the result of the fixation of a considerable part of organic substances by the mineral part of the soil.

4. The humic acids of the foregoing soils are characterized by a low optical density and a high resistance to the coagulating action of electrolytes (CaCl₂). This, as well as the data on their elementary composition (in particular, the narrow C:H ratio) point to the low degree of condensation of the aromatic nucleus of humic acids in the red earths and lateritic soils.

5. The close amino-acid composition of humic substances in the red earth and lateritic soil is an evidence of the similar formation of these substances.

6. There were no essential differences in the nature of humus in the red earths and lateritic soils of the Chinese People's Republic and Democratic Republic of Vietnam, as well as in the red earth from Chakva (USSR) in relation to the parent materials. Weathering and soil formation apparently modified the parent materials to such a degree that the main role in humus formation in the soils studied is played by bioclimatic conditions.

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SOLODS AND SOLODIZED SOILS OF THE ARID-STEPPE AND DESERT-STEPPE BELT OF THE IRTYSH REGION NEAR SEMIPALATINSK

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Right after the classical work of Gedroys (8), who substantiated the independent importance of the process of soil solodization, was published, a considerable number of investigations relating to this problem appeared (1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28). We can consider it an established fact that solods develop not only from solonchets as a result of their leaching by surface water and accompanying physicochemical processes (8, 13), but also from certain solonchetic and slightly saline soils under the influence of repeated leaching by surface waters and the action of slightly mineralized alkaline (sodium) solutions which are periodically introduced by comparatively shallow ground waters (3, 16, 17, 22, 24). In addition to this, a substantial role is played in solodization by temporary water-logging or the periodic excess wetting of the soil surface (28, 15, 24), which increases the mobility of iron compounds as a result of the activity of anaerobic bacteria. The accumulation of amorphous silica in solodized soils is attributable not only to physicochemical factors (8, 13), but also to biological processes (7, 26, 27, 19), and to its possible precipitation from molecular solutions added by ground and soil water flow (4, 7).

It must be noted that the majority of the foregoing papers deal with solodized soils under conditions of adequate wetting in steppe and forest-steppe regions. Only a small number of papers (1, 6, 14, 19, 20, 23) examine this process under more arid natural conditions.

The authors of the present paper investigated solodized soils and solods in the extremely arid areas of the Irtysh region near Semipalatinsk. They are found here both in the belt of dry, feather-grass—sheep's fescue steppes and dark chestnut soils, and in the adjoining wormwood-sheep's fescue desert steppes and light-chestnut soils southwest of the northern part of the belt.

Solods and solodized soils are most common in the Korostelev steppe and in the level part of the left bank of the Irtysh River, where they are found primarily in areas with saline soil-forming parent materials represented mostly by Tertiary clays covered in places by a sheet of Quaternary clay loam. In addition, solodized soils are widespread in pine forest strips (23).

According to the data of the Semipalatinsk meteorological station, the climate of the region under discussion is characterized by a mean annual precipitation of 275 mm, 177 mm of which falls during the warm period. The mean annual air temperature is 3°C, that of the warmest month, July, is 22.2°C, and that of the coldest month, January, is -16.2°C. The duration of the warm period is about 200 days. The average wind velocity is 3.7 m sec, while in the winter it is 4.1 m sec.

The solods and solodized soils of the foregoing region develop in relief depressions and derive additional moisture from surface runoff water, and in a number of cases from capillary moisture flow from close-by, slightly mineralized ground waters. Depending on the nature of additional moisture, the nature of the soil-forming parent material, and relief, solods or soils of other groups form here, which are modified by solodization processes. The most widespread among these are meadow-steppe solods (under shrubs), solodized meadow-chestnut soils (light and dark), and solodized meadow soils.

Meadow-Steppe Solods (under shrubs) are found both in the belt of arid steppes as well as in desert steppes. They form in relief depressions among continuous massifs of steppe and meadow-steppe solonchets, or their complexes. These depressions may originate either from suffosion (sinkholes) or suffosion-erosion (hollows, etc.). Vegetation is represented by almost continuous brushwood (pea tree, spirea, daphne, Tartar honeysuckle, and sometimes birdcherry and dog rose), reaching 1.5-3 m in height and having a canopy density of 70%-80% and more. For this reason large snowdrifts accumulate here in winter, while in the spring conditions are created for the intense leaching of the soils by cold snow waters. Solods form both where the ground water is deep and where it is moderately deep. According to the structure of their profile and morphological indications these soils are similar to typical forest solods, differing from them only slightly by their shallower profile. They are characterized by a horizon of dead plant litter (A_0) 5-10 cm thick; by the presence of a solodized, structureless eluvial horizon, 25 cm thick, containing humus in its upper part (A_1) and being light colored and having no humus coloration in its lower part (A_2); by the presence of a nutty, more

finely textured illuvial horizon (B) about 20-30 cm thick; and by parent materials (C) rich in carbonates in their upper part and the leachings of water-soluble salts. The actual profile of these soils in the arid-steppe belt has the following appearance.

Profile 660. It was described on September 24, 1958, 8 km to the southeast of the village of "Sladkiy Kolodez'" (approximately 90 km to the northeast of Semipalatinsk) in a large low-lying plain with complex soil and vegetation conditions. The main background is created here by meadow-steppe, solonchakized, medium-thick, prismatic-nutty clay loam solonchaks under wormwood-sheep's fescue vegetation. Meadow-chestnut solonchak soils under wormwood feather-grass sheep's fescue vegetation with pepper-saxifrage are found in poorly defined, small microrelief depressions. The soils described in the following profile are found in large sinkhole-like depressions. Vegetation is represented here by thickets of steppe pea trees, spirea daphne, and smaller amounts of honeysuckle. The height of the shrubs varies from 120-150 cm to 2.5-3 m, while their density is 70%-80%. Among the grasses there are wormwood, tarragon, feather-grass, sheep's fescue, melic, lyme grass, and meadow grass. The soil effervesces from hydrochloric acid at a depth of 55 cm. There are no visible salt accumulations at a depth of 200 cm. Ground water is at a depth of 4-5 m.

A_0 0-10 cm. Cinnamon-brown, slightly decomposed on top (0-6 cm), semi-peaty, dead shrub litter, almost free of mineral particles at the bottom.

A_1 10-25 cm. Dirty-gray, slightly moist, compact, rooty, blocky, medium clay loam.

A_2 25-35 cm. Light-gray with a slight brown tinge, damp, compact, slightly rooty, silty-powder-like-scaly, slightly laminated, medium clay loam.

B 35-55 cm. Brown, whitish from silica powder on top, and on the bottom glossy, damp, compact, slightly rooty, nutty, porous, clayey.

C_1^C 55-105 cm. Pale yellow-yellow-brown with whitish tongues and large carbonate spots, damp, compacted, slightly rooty, slightly nutty, fine clay loam.

C_2 105-200 cm. On top (down to 135 cm) yellow-brown with black manganese-like spots, below reddish-brown, slightly moist, compacted, slightly nutty, fine clay loam.

The morphological appearance and conditions of the position of soils in the desert-steppe belt are more or less the same. Thus, Profile 664, described on September 25, 1958 is 11.3 km to the southwest of the village of Muzdybay (approximately 25 km to the southeast of Semipalatinsk) on the left bank of the Irtysh River in a gently undulating, sometimes hilly high plain consisting of Tertiary deposits and leveled Paleozoic hilly monadnocks. It has similar morphological indices and the following horizon thicknesses: A_0 —5 cm; A_1 —11 cm (5-16 cm); A_2 —14 cm (16-30 cm); B—18 cm

(30-48 cm); and C—below 48 cm. It effervesces from hydrochloric acid from a depth of 55 cm. There are no visible salt accumulations to a depth of 150 cm. The ground water is deep, but there are indications of the formation of a temporary water table in the second meter below the surface, which is evidenced by rusty and gleyey spots. Such soils are found in wide, flat-bottomed depressions under shrubs surrounded by fine, solonchakized desert-steppe solonchaks, occupying more elevated surfaces.

In their chemical and physicochemical properties (Tables 1, 2, and 3) these solonchaks have a lot in common with the solonchaks of the aspen stands in the Irtysh region near Pavlodarsk (24). If we disregard the upper horizon (A_0), which consists entirely of slightly decomposed organic matter, then, according to the humus content in their A_1 horizon, these soils belong to the category of slightly humic soils (2%-6%). The distribution of humus is uneven along the profile, its content often increases in the illuvial horizon (in the soils with a predominant leaching regime, Profile 664).

The total nitrogen content is in relation to the humus content of the soils. According to the relative content of total nitrogen in the humus (C:N) there is no essential difference between the foregoing soils and zonal soils, which is apparently attributable to the weak participation of the root systems of grasses in the formation of humus in solonchaks. Fulvic acids predominate in the composition of humus; their relative content in the solonchak horizon proper (A_2) decreases, while it increases sharply in the illuvial horizon, primarily because of their more stable forms (II and especially the III fraction). The amount of highly mobile brown humic and associated fulvic acids (I fraction) is also great, but decreases with depth. The increase with depth of the relative content of fulvic acids, which differ from humic acids by their simplified structure, and the relative decrease of humin (insoluble residue) in this direction, together with the relative accumulation of the less mobile fractions of humic acids in the more deeper soil horizons, points to the illuvial nature of humus in these horizons. Strange as it may seem, there is a similarity between the group composition of humus in the foregoing soils and that of sod-podzolic soils (5), even though their fractional humus composition is rather different. As far as the characteristics of the organic matter in the foregoing solonchaks is concerned as compared to zonal light-chestnut soils, there is a considerable difference in the humus of these soils, according to data available in the literature for Central Kazakhstan (12). It is expressed in the relatively high content of humic acids in light-chestnut soils.

The content of water-soluble salts in the profile of the foregoing solonchaks is very insignificant, even though their content in the upper horizon is slightly higher, possibly because of the mineralization of plant residues. The alkalinity of the soils is also small and only increases somewhat in the carbonate horizons.

A characteristic quality of the foregoing soils, to judge by the sum of exchangeable cations, is the considerable increase of the exchange

SOLODS AND SOLODIZED SOILS

Table 1

Chemical and physicochemical properties of solods and solodized soils in the Irtys region near Semipalatinsk^a

Profile Number	Depth, cm	Humus, %	Nitrogen, %	C:N	CO ₂ , %	Free SiO ₂ , %	Available forms, mg/100 g of soil				Exchangeable cations, meq/100 g of soil					pH of water suspension
							Hydrolyzable N	P ₂ O ₅	K	Ca	Mg ⁺⁺	Na ⁺	K ⁺	H ⁺	Sum	
660	0-10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6,3
	10-20	2,4	0,15	9,3	—	1,69	3,6	7,8	77,1	13,2	6,6	0,1	0,8	3,3	24,0	6,6
	25-35	1,2	0,09	7,7	—	0,65	2,7	3,4	39,9	11,4	1,9	0,1	0,4	2,1	15,9	6,8
	40-50	0,1	0,08	8,0	—	0,39	1,3	1,5	49,8	13,2	7,5	0,1	0,8	1,8	23,4	6,8
	80-90	—	—	—	7,2	0,25	—	—	—	—	—	—	—	—	—	7,8
	190-200	—	—	—	3,5	—	—	—	—	—	—	—	—	—	—	8,5
664	5-15	6,1	0,37	9,5	—	0,81	5,7	2,4	29,3	22,5	6,5	0,1	0,2	4,8	34,1	6,3
	20-30	0,2	—	—	—	0,76	1,8	1,8	17,1	9,4	None	0,1	None	2,8	12,3	6,3
	35-45	1,2	0,10	7,3	—	0,29	Trace	2,4	33,2	13,0	3,7	0,1	0,3	2,0	19,1	7,0
	60-70	—	—	—	0,3	—	—	—	—	—	—	—	—	—	1	7,0
	130-140	—	—	—	0,8	—	—	—	—	—	—	—	—	—	—	8,0
630	0-10	3,6	0,23	9,0	—	4,34	—	—	—	19,0	None	0,1	0,7	—	19,8	7,2
	18-23	1,1	0,08	7,5	—	0,96	—	—	—	7,6	2,9	0,2	0,3	—	11,0	7,7
	25-35	0,8	0,07	6,7	—	0,56	—	—	—	3,8	7,6	0,2	0,5	—	12,1	7,9
	70-80	—	—	—	3,6	—	—	—	—	—	—	—	—	—	—	9,0
	140-150	—	—	—	4,6	—	—	—	—	—	—	—	—	—	—	9,0
658	0-10	3,6	0,20	9,6	—	2,8	—	—	—	11,1	10,3	0,3	1,0	—	22,7	6,6
	15-25	1,3	0,09	8,6	—	0,56	—	—	—	3,8	9,5	0,2	1,0	—	14,5	7,2
	30-40	1,1	0,07	8,4	—	0,35	—	—	—	15,0	None	0,2	0,8	—	16,0	7,2
	60-70	0,7	0,06	7,1	7,5	0,11	—	—	—	—	—	—	—	—	—	8,0
	90-100	—	—	—	1,0	—	—	—	—	—	—	—	—	—	—	8,2
	250-260	—	—	—	3,7	—	—	—	—	—	—	—	—	—	—	8,5

^aThe analyses were made by: A. P. Andriyevskaya, T. N. Boynova, M. S. Yesova, I. S. Mezhenin, L. K. Putro, Ye. A. Solodnikova, R. F. Somsina, U. Sultanbayeva, V. S. Sukhenko, T. P. Turchaninova, and N. A. Shilova.

^bExchangeable hydrogen by hydrolytic acidity, determined according to the method of Kappen.
Note: Comma represents decimal point.

capacity in the illuvial horizon (B) as compared with the solodized horizon proper (A₂). The increased adsorption capacity of the A₁ horizon is due to the increased humus content in it. The adsorption complex is saturated primarily by alkaline earth cations, whereby the content of exchangeable magnesium is high. The content of alkali cations in the adsorbed state is insignificant (up to 4% of the sum of cations), whereby there is noticeably more potassium than sodium. An important characteristic of these soils is the noticeable hydrolytic acidity, which is higher in more humic soils. The reaction of the soil solution in the illuvial horizon is neutral, in the eluvial horizon it is weakly acid, and in the carbonate horizons it is alkaline. The content of amorphous silica reaches 1%-1.5%.

The results of particle-size analysis (Table 4) substantiate the sharp differentiation in the particle-size composition of the profile of the foregoing soils, whereby coarse silt and fine sand particles predominate in the eluvial hori-

zons (A₁ and A₂), and the content of clay particles increases sharply in the illuvial horizon (B). Microaggregate analysis points to the considerable structurelessness of the eluvial horizons of solods. There is a rather sharp increase of water-stable aggregates in the illuvial horizon, which is in conformity with the characteristics of the fractional composition of humus and the increase in the content of fine elementary particles in this horizon.

The results of chemical, physicochemical, and particle-size analyses confirm what was said earlier about the formation of the foregoing soils primarily under the influence of their leaching by surface waters. This is evidenced by: the leaching of the soil profile from readily-soluble salts to a considerable depth; the low content of exchangeable alkali cations and the predominance of adsorbed potassium; the illuvial nature of humus in the lower soil horizons; the neutral and weakly acid reaction of soil solutions in the upper horizon; and also by the rather deep location of ground

Table 2

Content of water-soluble substances in solods and solodized meadow soils in the Irtysh region near Semipalatinsk, in % of air-dry sample^a

Prof. No.	Depth, cm	Solid residue	Alkalinity		Cl ⁻	SO ₄ ⁻⁻	Ca ⁺⁺	Mg ⁺⁺	Na ⁺ by difference
			HCO ₃ ⁻	CO ₃ ⁻⁻					
660	10—20	0,089	0,009	None	0,007	0,006	0,003	0,001	0,007
	40—50	0,071	0,010	"	0,002	None	0,003	0,001	0,001
	80—90	0,063	0,033	"	0,004	0,001	0,008	0,003	0,004
	190—200	0,075	0,034	"	0,007	None	0,005	0,006	0,003
664	5—15	0,171	0,007	None	0,016	None	0,008	0,002	Trace
	20—30	0,078	0,003	"	0,003	"	0,002	0,001	None
	35—45	0,093	0,019	"	0,004	0,003	0,007	0,001	0,001
	60—70	0,106	0,021	"	0,007	None	0,009	0,001	Trace
	130—140	0,095	0,021	"	0,017	"	0,010	0,001	0,005
658	0—10	0,148	0,016	None	0,020	0,003	0,006	0,002	0,009
	30—40	0,125	0,012	"	0,010	None	0,005	0,001	0,003
	90—100	0,078	0,021	"	0,016	0,003	0,007	0,001	0,010
	250—260	0,206	0,066	0,002	0,028	0,006	0,004	0,002	0,037

^aThe analyses were made by P. I. Pushkina.

Note: Comma represents decimal point.

Table 3

Group and fractional composition of humus in meadow-steppe (under shrubs) solod in % of total organic carbon^a

Profile Number	Depth, cm	Total carbon in % of soil	Decalcinate	Hydrolylate	Insoluble residue	Humic acids				Fulvic acids				Ratio between the C of humic acids and the C of fulvic acids
						Fractions				Fractions				
						1	2	3	Sum	1	2	3	Sum	
660	10—20	1,41	21,1	9,5	16,5	15,4	1,1	5,2	21,8	17,1	4,7	9,3	31,1	0,7
	25—35	0,71	24,9	11,0	9,4	7,8	9,2	6,9	23,9	13,2	5,2	12,4	30,8	0,8
	40—50	0,59	29,3	15,6	6,3	—	6,1	6,8	12,9	13,1	8,7	14,1	35,9	0,4

^aThe analyses were made by M. B. Varshavskaya.

Note: Comma represents decimal point.

water. True, if we consider the relatively shallow depth and the small thickness of the carbonate-illuvial horizon, we have the basis to assume that the temporary water table in spring, which interferes with the more intense leaching of the soil, has a certain influence on soil formation. However, the well-defined, loose litter of dead plant residues inhibits evaporation from the soil surface and upward moisture flows originate here primarily under the influence of transpiration. If we consider that the root zone is more than 1 m thick, we may safely state that the role of upward flow of weakly mineralized solutions is insignificant, especially in the upper soil horizons. This is also evidenced by the very insignificant increase of the salt content (including sodium and chlorides) in the upper horizons (Table 2). In this case it is more safe to assume that the predominant role is played here by downward flow of very weakly mineralized solutions

arising both as a result of the decomposition of the litter and as a result of the dissolution and washing of salts by surface waters draining from the surrounding solonetz areas. There is also no doubt that a not less considerable role is played by the periodic supersaturation in spring of the upper soil horizons lying above the illuvial horizon (as a result of the melting of snowdrifts accumulating in the shrubs and the drainage of surface water into relief depressions). Precisely these processes lead to the formation of the solods characterized earlier.

We may assume that the solods developed here from the surrounding solonetztes, but apparently only after having gone through an intermediary stage of either first solonetzic and then solodized meadow-chestnut soils, or solodized meadow-steppe solonetztes. This is evidenced by the analogous spatial alternation of soils found during the transition of solonetztes to

SOLODS AND SOLODIZED SOILS

Table 4

Particle and microaggregate (bottom row of numbers) composition of solods and solodized soils of the Irtysh region near Semipalatinsk, in % of absolutely dry sample^a

Profile Number	Depth, cm	Hygroscopic moisture, %	Loss of treat. with HCl, %	Particle diameter, mm										% of water-stable aggregate
				>3	3-1	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	< 0.001	< 0.01		
												According to anal.	According to loss	
660	10-20	1,6	2,9	None			28,4	33,4	8,5	16,9	8,9	34,3	36,0	31,7
	25-35	1,8	7,8	"		5,0	48,4	40,1	3,7	2,6	0,2			
				"			21,7	36,0	7,8	14,4	12,3	34,5	39,2	
	40-50	3,6	4,6	"		1,7	48,0	38,6	4,3	7,1	0,3			
	80-90	2,0	21,7	"			4,1	34,3	7,8	15,2	34,0	57,0	59,8	
				"		3,5	41,6	38,6	4,6	9,2	2,5			
664	15-25	3,0	4,3	1,5	5,5	4,4	31,0	19,2	7,7	13,4	14,5	35,6	37,4	35,3
				1,5	5,5	20,6	49,3	20,0	0,9	3,5	0,2			
	20-30	0,6	1,7	5,1	0,2	5,1	36,3	23,6	9,5	18,4	5,2	35,1	35,8	
	35-45	2,8	3,8	5,1	0,2	5,3	50,3	31,2	6,5	6,1	0,6			
				3,9	3,1	3,9	30,7	11,3	7,5	10,6	29,1	47,2	48,8	
	60-70	5,8	3,2	3,9	3,1	6,3	57,8	22,8	2,9	6,1	1,0			
630	130-140	1,2	5,9	8,3	2,6	3,2	12,6	19,6	18,0	24,0	16,8	58,8	60,2	61,0
				8,3	2,6	3,8	19,7	42,9	15,3	14,4	1,3			
				8,3	2,6	3,8	19,7	42,9	15,3	14,4	1,3			
				16,5	2,0	4,6	29,6	17,4	13,0	17,0	10,5	40,5	43,0	
658	0-10	3,6	3,8	None		None	19,4	32,4	15,8	12,8	15,8	44,4	46,7	39,4
				"		18,3	39,3	33,3	5,4	3,6	0,1			
	18-23	2,4	2,5	"		None	35,7	24,9	12,2	12,2	12,5	36,9	38,4	
				"		4,4	39,7	40,9	5,3	9,2	0,5			
	25-35	3,8	4,3	"		None	24,6	19,5	7,0	13,3	31,3	51,6	54,2	
				"		4,9	39,6	39,3	4,5	8,2	3,5			
658	70-80	3,6	13,0	"		None	21,9	31,5	4,9	10,7	18,0	33,6	41,4	39,7
				"		"	23,7	29,4	3,7	7,3	21,4	32,4	41,1	
	140-150	1,8	14,5	"										
				"										
				"										
				"										
658	0-10	3,0	4,7	None			21,0	27,3	10,1	15,3	21,6	47,0	49,8	—
	15-25	3,0	6,7	"			26,4	18,3	8,2	12,9	27,5	48,6	52,6	
	30-40	3,2	10,3	"			19,5	17,6	2,0	11,0	30,8	43,8	56,3	
	90-100	1,2	19,1	"			52,7	14,8	1,6	2,8	17,8	22,2	28,4	
	250-260	1,6	13,3	"			23,1	29,3	5,6	3,6	25,1	34,3	42,3	
				"										

^aThe analyses were made by Yu. N. Zhdanova.
Note: Comma represents decimal point.

solods. The more important role of the seasonal vertical migration of alkaline soil solutions during the primary stages of transition of solonetz to the foregoing solods is also evident. The importance and intensity of these migrations decrease gradually in the final stages of this process when the solods almost entirely lose the features of physicochemical solonetzization and salinization even in deep horizons, and when upward soil solution flows do not sufficiently regenerate the saturation of the upper soil horizons with alkali cations. Of course, in order to be able to judge the processes of solods and solodized soil formations more accurately, it is necessary to conduct seasonal observations on the dynamics of soil formation.

Solodized Meadow-Chestnut soils, as solods, are widespread in the arid-steppe and desert-steppe belt. They are found in depressed areas among solonetz complexes and sometimes also edge the meadow-steppe solods described earlier. The vegetation is represented by a usually shrubby meadow-steppe. In the desert-steppe belt it often consists of a continuous growth of steppe pea trees and spirea, however, more moisture-loving shrubs (daphne, Tatar honeysuckle, European birdcherry and dog rose) are absent on these soils. Solodized meadow-chestnut soils may develop from meadow-steppe solonetz as a result of their natural self-melioration under a leaching regime, or from solonetzic meadow-chestnut soils under conditions of leaching by fresh snow

meltwater, or by weakly mineralized surface runoff waters which drain from the surrounding complex solonetz areas.

Among solodized meadow-chestnut soils there are dark and light soils, depending on zonal conditions. The first develop in the dark-chestnut soil belt and the second, among light-chestnut soils. In addition there are moderately and slightly humic species among the two. The latter usually develop from solonetztes, while the moderately humic species develop from meadow-chestnut soils. Finally we can distinguish very humic meadow-chestnut soils developing from solonetzic or solodized meadow soils when they become steppe-like.

Below you will find the description of solodized meadow-chestnut soil developed from meadow-steppe solonetz.

Profile 630 was described on September 27, 1958, 3 km to the northwest of the village of Taldy-Kurgan (approximately 45 km to the southeast of Semipalatinsk) on the left bank of the Irtysh River in the desert-steppe belt of a flat-bottomed depression dissecting a leveled small-hill area and adjoining the flood-plain terrace of the Char River. Soil and vegetation are complex, represented by solonchakized, meadow-steppe (semi-hydromorphous), moderately lumpy-nutty, fine clay loam solonetztes under a wormwood-saltbush vegetation with *Atropis*, and solodized meadow-chestnut soils in various ratios. Solodized meadow-chestnut soils occupy hardly-noticeable, wide microrrelief depressions covered with sheep's fescue, *Stipa capillata*, Austrian wormwood, steppe sedge, and spirea. Black-eyed Susan and wormwood (tarragon and oriental wormwood) are found singly. The density of the grass stand is 80%-90%. The soil effervesces from hydrochloric acid at a depth of 42 cm. There are no visible accumulations of readily-soluble salts to a depth of 150 cm. Hardly noticeable veiny carbonate precipitations are found from a depth of 50-110 cm.

A₁ 0-18 cm. Brownish-gray, slightly moist, compacted, rooty, granular to powdery, medium clay loam.

A₂ 18-23 cm. Yellowish-light-gray, damp, compacted, slightly rooty, layered-blocky, medium clay loam.

B₁ 23-42 cm. Dark-brown, damp, compact, slightly rooty, prismatic-nutty fine clay loam.

B₂^C 42-50 cm. Brown, damp, compact, prismatic-nutty, fine clay loam.

C₁^C 50-110 cm. Yellow-brown, damp, compacted, vaguely nutty, medium clay loam.

C₂ 110-150 cm. Dirty-gray, damp, compacted, medium clay loam.

The chemical, physicochemical, and physical properties (Tables 1 and 4) indicate that: the humus content of these soils is low, but slightly higher than that of zonal soils (light-chestnut); the amount of humus decreases sharply in the solodized horizon (A₂); the con-

tent of free silica is high in the upper horizon; the illuvial horizon (B) is well defined, not only morphologically, but also as far as the increase of clay and of the exchange capacity are concerned; there are no noticeable amounts of adsorbed alkali cations, represented primarily by potassium, in spite of the pronounced "physical" or residual solonetzization (in the form of deep illuvial horizons); and not only the solodized horizon (A₂), but also the entire A horizon, which is detected by its insignificant content of water-stable microaggregates, is structureless to a high degree. All this serves as evidence that the given soils went through a solonetzic stage in the past, and were later leached from salts as a result of a change in the moisture regime. The biological activity of higher and lower organisms, which increased against this background, lead to the gradual and almost complete disappearance of physicochemical solonetzization and the formation of solodized soils. That this process took place exactly in the foregoing form is evidenced by the connection between the illuvial horizons of these soils and the neighboring meadow-steppe solonetztes, and also by the low humus content and the light color of the upper horizons of solodized soils. However, as we have mentioned earlier, other ways for the formation of solodized meadow-chestnut soils are possible.

Solodized Meadow Soils are comparatively rare, they occur in the arid-steppe zone, primarily in the Korostelev steppe. They occupy the flat bottoms of estuarine depressions, bordered by very pronounced ancient shore banks (up to 1 m high)—witnesses of the former more prolonged inundations of these surfaces. Vegetation is represented by mixed grass meadows, steppe-like in places. The soil-forming parent materials consist of weakly stratified clay loam deposits. The weakly saline ground waters are found at a depth of 2.5-3 m. The morphological characteristics of solodized meadow soils can be seen from the following description.

Profile 658 was described on September 24, 1958, 6 km to the southeast of the village of Sladkiy Kolodez' (approximately 90 km to the northeast of Semipalatinsk) in the arid-steppe zone of a wide, flat depression bordered by low ancient shore banks. Vegetation is represented by a steppe-like meadow consisting of sedge, reedgrass, licorice, Austrian wormwood, British inula, as well as meadow grass, *koeleria*, sheep's fescue, Siberian crepis, yellow alfalfa, and prostrate knotweed. The density of the grass stand is 100%. The soil effervesces from hydrochloric acid at a depth of 45 cm. There are no visible accumulations of readily-soluble salts. Carbonates appear in the form of rare whitish spots at a depth from 45-85 cm. Weakly saline ground water is found at 270 cm.

A₁ 0-14 cm. Dark-gray, moist, becomes lighter in color and more gray when it dries, slightly compacted, rooty, granular to powdery, sandy fine clay loam.

B₁ 14-26 cm. Gray, damp, compacted, slightly rooty, blocky, sandy fine clay loam.

B₂ 26-42 cm. Brownish-gray, damp,

compacted, slightly rooty, granular-nutty, clayey.

BC 42-80 cm. Brown with an ochrish tinge, slightly moist, compacted, weakly-granular, clayey.

C₁ 80-114 cm. Pale yellow with an ochrish tinge, slightly moist, compacted, sandy loam with thin clay interlayers.

C₂ 114-150 cm. Yellow-brown with diffuse rusty and dark bluish spots, moist, compacted, clayey.

C_{3,4} 150-270 cm. Reddish-brown, moist, clayey on top and yellow-brown, wet, compacted clay loam on the bottom.

The morphological characteristics of solodized meadow soils may vary considerably, however there is always a structureless, upper humic A horizon in their profile, containing silica powder and often becoming lighter in color in the lower part (A₂), and also an illuvial B horizon, retaining in its lower part weak signs of residual solonetzization. The soil profile is usually leached of carbonates to a considerable depth and washed of readily-soluble salts.

The results of analyses of these soils (Tables 1, 2, and 4) confirm the presence of an illuvial horizon and its weak residual solonetzization, caused primarily by potassium, and point to a rather deep leaching of carbonates and an increased content of free silica in the upper solodized horizon, as well as to the weak mineralization of the ground waters which are found at a depth of about 3 m. Judging by the increased content of bicarbonates and the presence of sodium carbonate in the deep horizons of the soils, we can assume that the ground water is slightly salinized by sodium carbonate. Taking into consideration the slightly increased content of water-soluble salts in the upper and deeper soil horizons, we can state that the role of the vertical migration of weak saline solutions is more important in the formation of these soils.

The productive importance of the foregoing soils is small at the present time. The solods and solodized meadow-chestnut soils are used as not very productive shrubby pastures, while solodized meadow soils are used for hay fields. The productivity of these lands can be increased considerably by grubbing the shrubs on solods and solodized meadow-chestnut soils, leaving only strips of shrubs at the edges and across the prevailing winter winds for snow retention purposes. This would allow the sowing of forage crops, including vegetables and melon crops. Spring floods should be regulated on solodized meadow soils, and the species composition and productivity of natural grasses should be improved by corresponding agricultural practices.

Conclusions

1. Unusual meadow-steppe solods (under shrubs) and solodized meadow-chestnut soils, developing in relief depressions under shrubby

and meadow-steppe vegetation where the ground water is moderately deep and partly deep, are widespread in the arid-steppe and the northern part of the desert-steppe belt of the Irtysh regions near Semipalatinsk. Solodized meadow soils are found in firth-like depressions under meadow vegetation, steppe-like in places, where the weakly mineralized ground water is close to the surface.

2. The solods and solodized soils of the region under discussion possess all the major group characteristics and properties of corresponding soil formations, however, soils with a shallow profile and with a small content of adsorbed sodium in the illuvial horizon predominate among them.

3. The most common condition for the formation of solods and solodized soils in the region is the systematic leaching by meltwater and surface runoff water in spring of the originally solonetzic or solonetz soils, which at the present time are also subject to the influence of weakly mineralized, shallow ground water and temporary water tables. An essential factor in solodization is the short spring flooding (water-logging) of the upper soil horizons, as well as the seasonal alternation of intense downward flow of diluted soil water with less intense upward flow of weak alkaline solutions, exerting a considerable influence in the primary stages of solodization. The complex of biological and physicochemical processes taking place under these conditions leads to the formation of solods and solodized soils.

4. An important factor in the additional wetting of the foregoing soils under arid conditions is snow accumulation in winter in relief depressions and shrubs.

5. The productivity of the foregoing soils could be increased considerably by simple meliorative measures.

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MOISTURE REGIME OF SANDY SOILS IN THE PINE FOREST STRIPS OF IRTYSH REGION

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The pine forest strips of Kazakhstan are located in the zone of chestnut soils and occupy about 0.8 million hectares. The severe climatic conditions create difficulties in the planting of forests and reforestation. One of the most important and least studied problems in forest growing is the moisture regime of sandy soils in the Irtysh region, which is governed by the dryness of the climate and the hydrophysical properties of the sand. Vysotskiy (1) wrote that "the moisture regime of soils is the major factor of life and by the same token of soil formation."

Because of this we studied the moisture regime of sandy soils in 1956.

The experiments were made in the Kanoner-skiy Forestry, Pavlodar Oblast', in the village of "Teplyy ugol." The relief of the area consists of hummocks, 3-7 m high, elongated from the northwest to the southeast, composed of fine-grained sand of elluvial-eolian origin. The pine-forest sandy soils developing on the hummocks have a shallow (10-20 cm) and slightly humic (in the tenths of a percent) A horizon.

The subjects of study were: 1) a 17-year old Scotch pine stand with an initial density at the moment of planting of 6600 stems/ha (1 X 1.5 m) and 5000 stems/ha when the observations were made; 2) typical natural grass vegetation; and 3) bare sandy soil.

The stands were well-preserved in places, but thin here and there. As a rule, the plantings perished almost everywhere under the enclosed crowns of old pines, they were depressed at the periphery, and were in good shape in beds located in areas with midday shade. The observations were made in a well-preserved part of the plantation. The average height of the pines was 255 cm, their diameter at a height of 10 cm was 5 cm, and their projected crown area was 0.35-0.40. The grass vegetation under the stand was thin, and totally absent during the period of observation (it was destroyed). The ground water was at a depth of 513 cm on May 5 and at 541 cm on August 21.

The area with the grass vegetation was located under similar relief and soil conditions. It consisted primarily of *Stipa Joannis*, *Festuca Beckeri*, blue koeleria, squat sedge, *Artemisia* March., sand everlasting, and Volga campion.

The projected crown area was 0.45-0.50. The ground water was at a depth of 470-500 cm.

It must be noted that the experimental areas cannot be considered as forest, steppe, or a fallow field in the full sense of the words. They were in the form of elongated rectangles about 50 m wide, located at a distance of 100-150 m from each other. The results of microclimatic observations showed that the soil surface temperature in the open is 6°-8°C higher during the day and 3°-4°C lower at night than in the plantation; the wind velocity in the plantation is 2-3 m/sec lower, while there are no regular differences in the dryness of the air.

At the experimental areas we studied: 1) the hydrophysical properties of soils; 2) the water consumption by the pine stand; 3) the water consumption by the natural grass vegetation; 4) moisture losses by evaporation from the soil surface; 5) moisture losses by ground drainage; 6) the temperature regime of the soil and the air layer near the ground; and 7) ground-water depth.

The bulk density of the soil was determined with N. A. Kachinskiy's apparatus; field moisture capacity, by the flooding method; water intake rate, by the method of flooding a square area; particle-size analysis, by the Sabanin method, and maximum hygroscopicity, by the Mitscherlich method.

The transpiration of the pines was determined by the method of L. A. Ivanov with 5- to 7- replications, 4-6 days a month at 2-hr intervals; and the amount of needles was assessed from 5 model trees. When calculating the water consumption by the plantation we used the following number of transpiration hours per day: 14 in May, 14 in June, 12 in July, 10 in August, and 9 in September. Evaporation from the soil surface was studied by means of brass micro-evaporimeters with a surface of 96 cm² and a height of 8 cm. The observations were made 4-6 days a month with 2- to 3- replications, changing the monoliths every 2 hours. Soil moisture was determined by the thermostatic drying method on 3-4 samples.

The results of particle-size analysis showed that there are more than 95% of particles 0.05-0.5 mm in diameter and only 0.6%-3% of particles <0.01 mm in diameter. The low clay content is the reason for the low hygroscopicity and

Table 1

Average daily transpiration intensity and transpiration losses in the pine stand by months

Indices	from May 4	June	July	Aug.	to Sept. 16	May 4- Sept. 16
Transpiration intensity, mg/ g hr	138	180	120	111	149	—
Transpiration loss, mm	22,0	32,4	18,5	13,8	8,8	95,5

Note: Comma represents decimal point.

moisture capacity of the soils. Minimum moisture capacity (FMC) is the most important factor in the forest-growing capacity of sands and sandy soils (2). The FMC of the sandy soil studied by us was about 4%, while the moisture content in the upper meter of the soil at FMC was 60-65 mm. This is exactly that amount which can accumulate in the root zone. The water permeability of the soils insured the full absorption of precipitation and was 7.3-10.6 mm/min. The bulk density of the sand in the upper 0.5 m varied along the profile from 1.45-1.55 g/cm³, and reached up to 1.60-1.65 g/cm³ in the lower layers.

When digging up the roots we found that the main mass of the roots (90%) is concentrated in the upper 0.5 m, more than half of which are located in the upper 20 cm. Individual roots penetrate to a depth of 1.5 m and more; thus, inside a rotted root we found a braid of 4 roots from different pines reaching to a depth of 3.5 m. Dead roots were well-preserved below, while live roots were distributed along their periphery and were flat. There were none branching at a depth of 1.5-3.5 m, except for rare outgrowths 3-5 cm long, often in the "club" form. Such a distribution of roots in the dry pine forests of the Irtys region was also noted by Gayel' and Petrenko (2).

The most important aspect of the moisture regime is the transpiration rate of pines and the transpiration loss of the plantation. As we can see from Table 1, transpiration is comparatively intense in spring when there is sufficient moisture in the soil. Frequent precipitation in June maintained soil moisture close to the minimum moisture capacity. At this time the intensity of transpiration increased. In July and August the soil moisture became depleted and, consequently, transpiration decreased. Precipitation in the last days of August again increased the water consumption of pine.

It must be noted that the transpiration rate of pines, even with relatively high soil moisture (MMC) and a high intensity of meteorological factors, rarely exceeded 250 mg/g per hour. At the same time, Olovyanikova (6), who made observations on the transpiration of 4- to 5-year old pines in the same area and at the same time we did, found that the average transpiration rate of pine in narrow-strip plantings in May and June was 302 mg/g hr and 247 mg/g hr, respectively, and in wide-strip plantings even 488 mg/g hr and 400 mg/g hr. The reason for such differences is probably the different

ratio between suction and transpiring pines in various plantings.

The transpiration loss of the plantation depends on transpiration rate and the amount of needles. According to our determinations, there was 4.15 metric tons ha of needles in the plantation. As we can see from Table 1, the moisture loss by transpiration was highest in May and June, at a period when the plants were best supplied with moisture.

Moisture evaporation from the soil surface depends greatly on the moisture content of its upper layer, and, consequently, on the number of days with precipitation. In the first days after a rain, evaporation from the soil was 5-10 times higher than during a dry period.

As we can see from Table 2, the moisture loss by evaporation varies from 0.21-3.4 mm/day. During the first days after precipitation evaporation from the bare soil is somewhat higher than under vegetation, while during the rest of the days the difference does not exceed the accuracy of the method. Altogether evaporation from the soil in the stand was 86% and under the grass vegetation, 89% of that from bare soil.

The nature of the drying of the soil under vegetation during the growing period is shown by moisture chronoisopleths (Fig. 1). In early May the moisture content in the first and second meter depth of the soil under the pine stand is considerably below field moisture capacity. Precipitation in May increased the amount of moisture in the upper 2 m of the sand, while ample precipitation in June wetted the upper 3 m of soil and was partly used in recharging the ground water. The upper 3 m of sand under grass vegetation were completely wetted in the second half of May. Precipitation in June continued to penetrate to the ground water.

The chronoisopleths show that the vegetation draws moisture primarily from the upper 0.5 m of soil. The drying of the root zone begins in July and reaches a maximum, close to wilting moisture, by September. The soil dries almost in the same way under the pine stand as under grass vegetation. Only in September does the moisture content of sand in the second meter under the pine stand decrease. The intensity of drying in the upper meter of the soil is considerably higher under grass vegetation, which is attributable to the more full utilization of soil moisture by steppe grass vegetation.

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Table 2

Areas	Days of observations																			
	May 14	May 22	May 24	May 25	June 6	June 13	June 20	June 21	July 5	July 11	July 12	July 27	July 30	July 31	Aug. 1 ^a	Aug. 28	Aug. 30	Sept. 4	Sept. 5	Total of 19 days
In the pine stand	0.51	2.7	0.33	1.92	1.85	2.45	0.90	0.54	0.70	0.33	0.33	0.42	0.27	0.67	0.28	1.10	1.10	0.87	0.54	17.81
Under grass vegetation	0.49	2.4	0.61	2.0	1.53	2.85	1.05	0.53	0.69	0.28	0.30	0.48	0.28	0.56	0.22	1.20	1.70	1.00	0.57	18.71
From bare soil	0.65	3.4	0.48	2.0	1.90	3.30	0.88	0.57	0.76	0.41	0.33	0.40	0.21	0.61	0.23	1.83	1.30	0.97	0.55	20.78

Note: Comma represents decimal point.

Before examining the water balance data, let us describe the methods of determining moisture content and loss. Precipitation was measured by surface rain gages. We did not determine the moisture content from condensation because of the lack of a reliable method. Moisture losses by transpiration of the pine stand and by evaporation from the soil surface were determined by graphical interpolation of the data obtained. Subsurface drainage under the stand was determined from the difference between the moisture content and its losses by transpiration and evaporation, and under the grass vegetation, from the presence and rate of infiltration of "gravity-film" water (7). Interception was determined from the change in the moisture of sand under the crowns after rain (before a rain it was air-dry) at 50 points, and by the sprinkling method (4). The loss from grass transpiration was determined by difference.

Let us examine the data in Table 3. About half of the mean annual precipitation fell in May and June, after which a dry period set in. Because of this, the moisture contents in the plots were at a level corresponding to the minimum moisture capacity of the soil up to July. In July and August the amount of moisture decreased in the upper 0.5 m, then in the first meter, and in September, in the second meter of the soil. The large amount of precipitation at the beginning of the growing period caused an increase in moisture losses by total evaporation. In spite of this, the pine stand used a relatively small amount of moisture, only 95 mm, for transpiration during the growing period.

According to the data of Olovnyannikova (6), the moisture loss by transpiration in wide forest strips in the same year was 100 mm from May-September, of which 82 mm were utilized by pine and 18 mm by grass. According to the data of Molchanova (5), pine stands used 146 mm on transpiration in the steppe zone. Kulik (3) established that a pine stand of 0.7 density on the Terek-Kum sands utilizes 180 mm, of which 130 mm are supplied by precipitation.

Grass vegetation uses more moisture by transpiration than a pine stand. This is attributable to the high transpiration rate of grasses, exceeding by 2-5 times that of pine (6).

Evaporation from the soil in vegetated plots was approximately the same, amounting to 38%-41% of the total loss, or 55%-57% of the amount of precipitation during this period. In addition, about 0.5 mm of moisture after each rain was intercepted by the crowns in the stand, and evaporated. As a result, the loss by evaporation from the crowns was 10% of the precipitation. In July and August, when low-intensity precipitation occurred, evaporation from the soil surface exceeded the amount of precipitation.

The moisture loss by subsurface drainage was only 10%-18% of the total loss, in spite of ample precipitation. There is apparently no subsurface drainage during the growing season in years with moderate moisture.

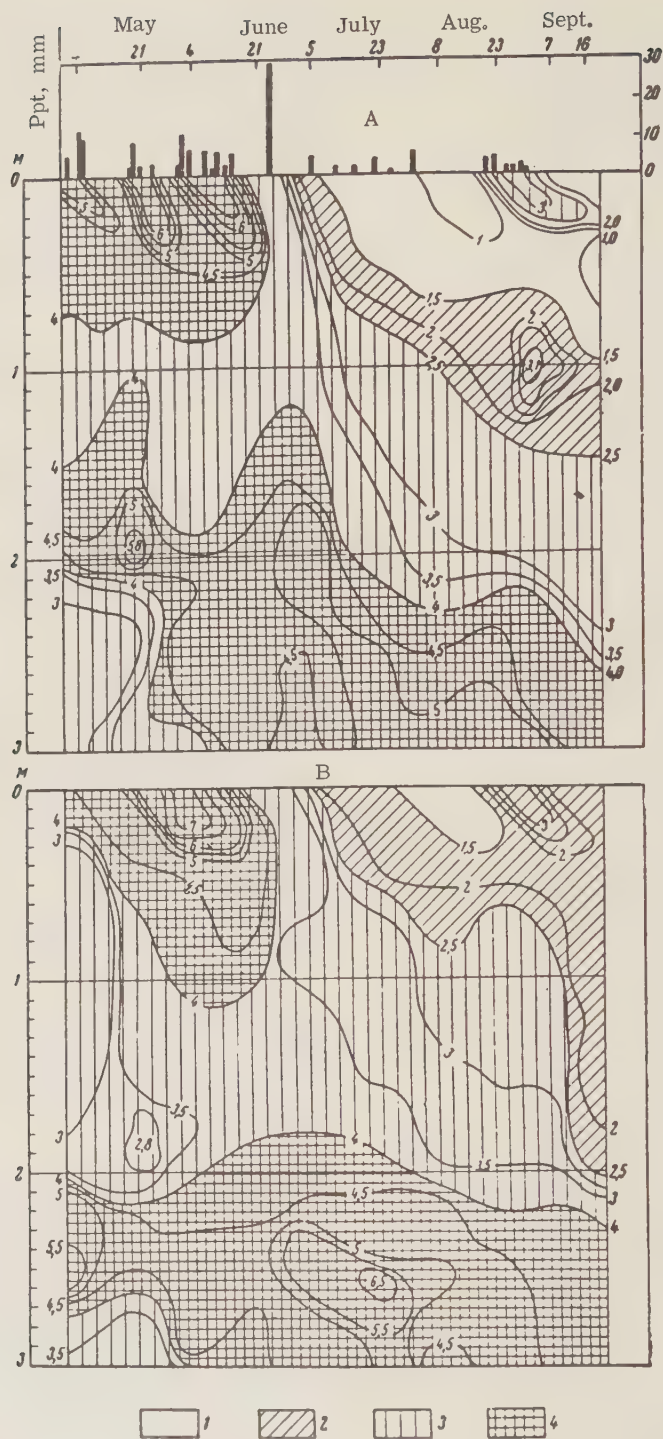


Fig. 1. - Moisture chronoisopleths

A - under grass vegetation; B - under the pine stand. 1 - 1%-1.5% (WM); 2 - 1.5%-2.5% (MMC-WM); 3 - 2.5%-4% (FMC-MMC); 4 - 4% of soil weight.

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Table 3

Moisture dynamics and balance in a pine stand and under grass vegetation

Elements of the balance	Days of observation									MMC	WM
	May 4	May 21	June 21	July 4	July 23	Aug. 8	Aug. 23	Sept. 16	May 4-Sept. 16		
Under pine stand											
Moisture 0-50 content	28	39	31	25	13	11	11	11	—	34	8
by 50-100	33	31	32	28	26	21	13	12	—	31	6
by 100-150	26	30	29	31	28	25	24	15	—	31	6
layers 150-200	31	25	32	34	33	29	28	21	—	31	6
0-200	118	125	124	118	100	86	76	59	—	127	26
Supply (+), loss (-)	+7	-1	-6	-18	-14	-10	-17	-17	-59	—	—
Precip. during period	32	67	30	14	7	4	22	22	176	—	—
Total loss, including	25	68	36	32	21	14	39	39	235	—	—
Evaporation fr. soil	10	30	11	12	11	6	17	17	97	—	—
Transpiration	13	33	11	12	8	6	12	12	95	—	—
Precipitation intercepted by crowns	2	5	3	2	1	1	3	3	18	—	—
Ground-water flow	0	0	11	6	1	1	7	7	25	—	—
Under grass vegetation											
Moisture 0-50 content	36	40	30	17	11	8	8	11	—	34	8
by 50-100	32	32	32	29	21	16	16	9	—	31	6
by 100-150	30	34	30	30	25	17	13	11	—	31	6
layers 150-200	36	31	32	34	31	30	19	19	—	31	6
0-200	134	137	124	110	88	71	56	50	—	127	26
Supply (+), loss (-)	+3	-13	-14	-22	-17	-15	-6	-6	-84	—	—
Precip. dur. period	32	67	30	14	7	4	22	22	176	—	—
Total loss, including	29	30	44	36	24	19	28	28	260	—	—
Evaporation	10	31	12	12	11	6	17	17	99	—	—
Transpiration	12	30	20	19	13	13	11	11	118	—	—
Ground-water flow	7	19	12	5	—	—	—	—	43	—	—

Conclusions

1. The moisture regime of sandy soils in the pine forests of the Irtysh region, which is determined by the dryness of the climate and the hydrophysical properties of the sand, promotes the development of pine stands on them, independent of ground-water depth.

The moisture capacity of the sand is such that it allows the accumulation of 65-75 mm of available moisture in the root zone at the beginning of the growing period. The remaining portion of autumn-winter and early spring precipitation recharges the ground water.

2. The water consumption (transpiration) of pine and grass vegetation under conditions of a dry climate depends primarily on the amount of available moisture in the root zone. A 17-year old Scotch pine stand on sandy soils of a low moisture capacity in the dry steppe of the Irtysh region used a relatively small amount of moisture (95 mm) for transpiration under favorable moisture conditions, which is the reason for the low site quality of tree stands (IV-V) in dry forests. Natural grass vegetation used a considerably larger amount of moisture (118 mm) under the same conditions, which shows the high competitive ability of steppe grasses.

3. The moisture loss by evaporation from

the soil surface during the growing season was 55%-57% of the amount of precipitation for the same period. In addition, tree crowns intercepted about 10% of the precipitation in a stand with 4.15 metric ton ha of needles.

4. Most of the root system (90%) of pines and grass vegetation is located in the upper 0.5 m of the soil. The amount of roots decreases sharply with depth and only individual pine roots penetrate below 1.5 m along the root channels of preceding plants.

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EFFECT OF THINNING ON THE MOISTURE REGIME OF SOILS AND THE GROWTH OF MASSIVE FOREST PLANTATIONS IN THE DRY STEPPE

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The establishment of stable forest plantations in the dry steppe zone is greatly complicated by moisture deficiency. Therefore, the whole complex of forest management practices must be directed here primarily toward the regulation of the moisture regime of the plantations. In addition to proper territorial distribution and a thorough selection of strains and types of mixtures, the stands must always be kept at a moderate density. Under the foregoing conditions weak trees perish and the best trees weaken when the stands are overcrowded. The overcrowded stands lead to severe moisture deficiency, whereby massive plantations on watersheds suffer greatly in contrast to strip plantations, which accumulate snow blown away from the spaces between the strips.

One of the most effective means of regulating the moisture available to plantations is thinning. In the present paper,¹ we give the results of investigations on the effect of thinning on the growth of plantations and the moisture regime of the soil.

The object of study was a 16-year old plantation consisting primarily of oak accompanied by European and downy ash with an underbrush of yellow acacia. It is located at the Derkul' Forest Experimental Station, Lugan' Oblast'. The area is situated on a gentle northern slope between forest strips (planted in 1897), representing a young growth of oak, ash, and elm. The soils are shallow, medium clay loam ordinary chernozems.

Investigations conducted here earlier (2, 3, 5, 6) showed that the main source of moisture for the plantation is the suspended moisture, while the role of summer precipitation is insignificant. Ash, whose root system and crown are well developed, uses the most amount of moisture.

To study the effect of the composition and density of a plantation on its moisture regime, the forest management group under the supervision of V. V. Popov set up a series of thinning experiments in 1951 and 1952, which included:

1) the clearing of all the underbrush, 2) clearing 50% of the accompanying trees (European and downy ash) and 50% of the underbrush, and 3) cutting all the accompanying trees and clearing all the underbrush. As a result, there were 4 experimental plots, including the control, covering 0.25 ha each. Their description is given in Table 1. The Laboratory of the Forest Institute of the Academy of Sciences of the USSR and the Derkul' Forest Experiment Station conducted complex investigations on these plots.

According to the results of the silvicultural investigations, thinning had a very favorable effect on the growth of the plantations (Table 1). The number of drying trees diminished, and the increment of oak and downy ash rose considerably. The only exception was the fourth plot, where the height increment of oak dropped. This was caused by the fact that here crown enclosure decreased to 0.4, thus not ensuring the secondary growth of oak. Nevertheless, even in this plot the volume increment decreased only slightly because of a sharp increase in trunk diameter. The increment of European ash did not change after thinning.

The distribution of the root system along the soil profile changed little after thinning (Table 2). As before, about half of the fine roots (1 mm in diameter) was located in the upper 15 cm of the soil. However, the total amount of fine roots decreased considerably after thinning. The mass of leaves (11) decreased to a lesser extent. As a result, the relation between the leaf mass and the root mass increased, which usually points to an improvement in forest-growing conditions.

There was no doubt that under arid conditions the water supply governs the growth of plantations. However, it was not clear precisely what changes in the moisture of the soil and plantations are the most essential. To solve this problem, measurements were made of the total moisture loss by transpiration of a plantation during the growing period, the transpiration of a single tree during the same period, the distribution of moisture by soil horizons, and the duration of the period when the plantation was supplied by readily and moderately available moisture.

The results of transpiration measurements (7, 11) showed that the total amount of moisture

¹ The work was conducted under the supervision of Prof. S. V. Zonn.

Table 1

Influence of thinning on the composition and growth of oak-ash forest plantation

Plot	Stand density	Number of trees				Increment of the plantation, m ³ /ha per year	Increment of oak		Dry oak trees, %, ^b
		Oak	European ash	Downy ash	Acacia		Height, cm/yr	Diameter %, ^a	
1	1,0	1984	1034	1384	3536	2,29	19,4	100	13,8
2	0,9	1822	1228	1228	—	3,56	26,5	131	4,8
3	0,8	1697	463	954	1768	3,48	24,6	182	2,8
4	0,4	1679	—	—	—	1,98	15,9	200	0,6

^aThe annual increment in plot 1 is taken as 100%.^bThe total number of oak trees in the plot is taken as 100%.

Note: Comma represents decimal point.

Table 2

Amount of roots (roots less than 1 mm in diameter) and leaves after the fourth year of thinning

Biomass and layers, cm		Plot							
		1		2		3		4	
		metric tons/ha	%	metric tons/ha	%	metric tons/ha	%	metric tons/ha	%
Roots	0—15	5,52	48	3,44	36	3,48	50	1,74	46
	15—50	2,88	26	3,56	38	1,65	24	1,16	30
	50—100	1,30	11	0,98	11	0,92	13	0,43	11
	100—200	1,65	15	1,40	15	0,93	13	0,50	13
	0—200	11,35	100	9,38	100	6,98	100	3,83	100
Leaves		7,30	—	9,03	—	6,14	—	4,42	—
Relation between roots and leaves		—	155	—	104	—	114	—	87

Note: Comma represents decimal point.

used by the plantation per unit area during the growing period decreased considerably after thinning, while evaporation from the soil surface and transpiration by grass increased (Table 3). An especially sharp decrease in transpiration losses (by more than half) occurred in plot 4, whereby this decrease was not caused by a decrease in transpiration rate, calculated per unit leaf mass, but by a decrease in leaf mass from thinning. Transpiration rate, on the other hand, after having increased during the first year after thinning, decreased to the level of the control plot in the second year. As a whole, the transpiration losses of the plantation exhibit a weak positive correlation with the magnitude of the increment ($r = +0.54 \pm 0.35$). The available data bring us to the problem of the evaluation of the relative moisture availability to the plantations. There is no generally accepted method for doing this (6).

It would probably be more correct to take the minimum field moisture capacity as the optimum soil moisture under conditions of a non-leaching water regime, and to consider the amount of moisture transpired during a certain time interval under constant moisture, equal to minimum moisture capacity, as the criterion of

the moisture availability to the plantations. In relating the actual transpiration losses of a plantation during this period to the criterion of moisture availability, we can evaluate the relative moisture availability to the plantation. For the plantations studied, the criterion of moisture availability for the growing period was evaluated at 480 mm (120 warm days with an average daily loss of 4 mm). In this case, the moisture availability to the plantation in 1954 (an unfavorable year as far as moisture conditions were concerned) was 0.23, and in 1955 (a more favorable year) it was -0.55. Thus, in the dry steppe moisture conditions for forest plantations on watersheds are rather severe.

A high correlation was found between the increment in tree diameter and the amount of transpiration moisture, averaging ($r = +0.83 \pm 0.15$) for a single tree. An especially high correlation was found for oak ($r = +0.89 \pm 0.10$). After thinning, the area of nutrition, and the roots and leaves of a single tree increase (11). This leads to an increase in increment and transpiration, which is especially high in oak and acacia and lower in downy and European ash (Table 4). The sharper reaction of oak to thinning is attributable to the fact that ash

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Table 3

Components of the soil moisture balance under a forest plantation during the growing period, mm of water

Year	Plot	Moisture contents in the layer from 0-2 m		Precipitation	Moisture loss		
		Initial	Final		Total ^a	Transpirational	By evaporation ^b
1952	1	660	400	148	408	—	—
	2	640	394	185	431	—	—
	3	628	398	190	418	—	—
	4	634	420	202	416	—	—
1953	1	726	400	92	418	—	—
	2	658	400	105	363	—	—
	3	670	400	108	378	—	—
	4	702	425	132	409	—	—
1954	1	531	390	170	311	115	196
	2	517	390	188	315	145	170
	3	512	390	197	319	91	228
	4	555	400	220	375	66	309
1955	1	644	395	138	387	276	111
	2	623	400	165	388	231	157
	3	642	395	158	405	227	178
	4	606	420	181	367	96	271
1956	1	586	400	115	301	—	—
	2	525	404	135	256	—	—
	3	498	410	122	210	—	—
	4	593	430	155	318	—	—

^aThe total moisture loss was calculated according to the formula $M_{in} - M_{fin} + Ppt$, where M_{in} and M_{fin} are the moisture contents in the soil at the beginning and at the end of the growing period and Ppt is precipitation.

^bThe moisture loss on evaporation was calculated from the difference between total and transpiration losses.

Table 4

Average moisture loss on transpiration for a single tree during the growing period

Tree	Plot	1954		1955		Tree	Plot	1954		1955	
		kg	%	kg	%			kg	%	kg	%
English oak	1	14,9	100	32,6	100	Downy ash	1	9,0	100	33,4	100
	2	18,8	126	28,3	87		2	23,5	261	40,6	122
	3	23,6	158	45,8	140		3	15,2	169	43,8	131
	4	39,5	265	55,8	171	Acacia	1	5,7	100	23,3	100
European ash	1	51,7	100	79,5	100		3	10,7	188	34,1	146
	2	66,3	130	106,0	133						
	3	53,3	104	102,0	128						

predominates in a thick plantation of a given composition, suppressing the growth of oak.

The participation of various soil horizons in the supply of moisture to the plantation was

evaluated by analyzing the dynamics of soil moisture. Since we knew that in the foregoing soils moisture moves slowly at a moisture content below minimum moisture capacity (10), the following assumptions were made: first, that

Table 5

Moisture uptake by the plantation from various soil layers, mm of water

Soil layer, cm	Plot				Soil layer, cm	Plot			
	1	2	3	4		1	2	3	4
1954					1955				
0-50	45	70	43	0	0-50	102	64	60	0
50-100	50	55	48	46	50-100	67	57	68	20
100-200	20	20	0	20	100-200	107	110	100	75
0-200	115	145	91	66	0-200	276	231	228	95

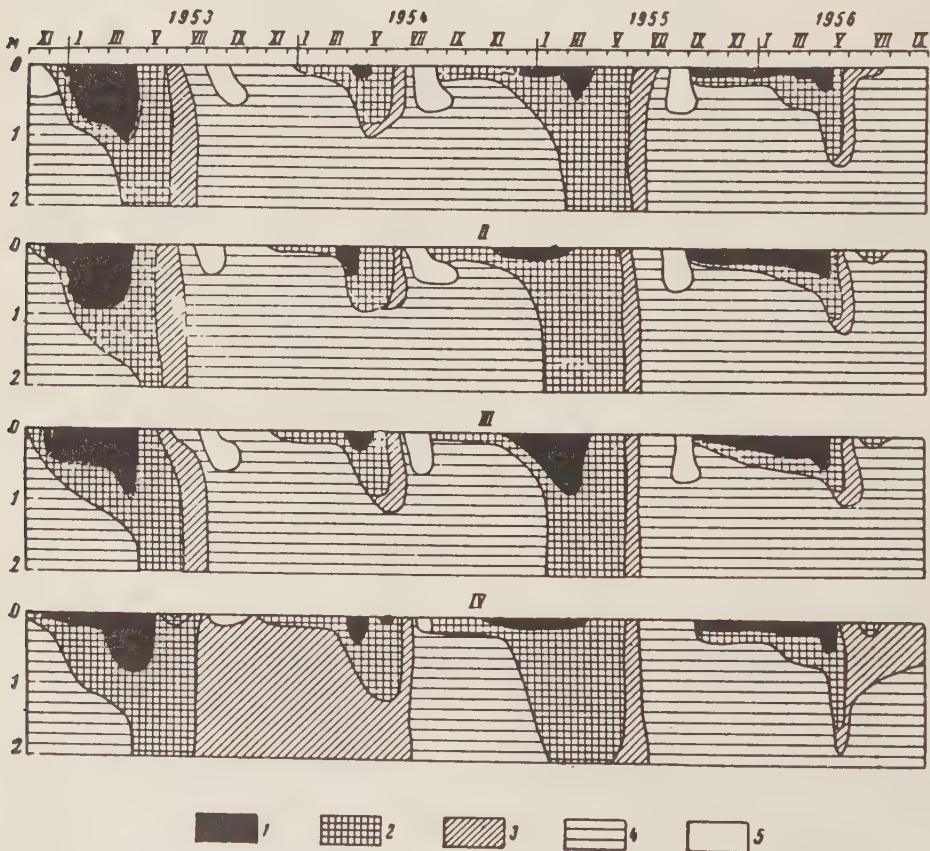


Fig. 1. - Dynamics of soil moisture available to plants

Plots: I - control; II - with cleared underbrush; III - with 50% of the accompanying trees and 50% of the underbrush cleared; IV - entirely cleared of accompanying trees and underbrush. Moisture category (according to availability to plants): 1 - excessive (more than FMC); 2 - readily available; 3 - moderately available; 4 - not easily available; 5 - unavailable.

the soil layer from which the plants derive moisture is limited to the root zone, approximated at 2 m (4), and, second, that moisture losses from evaporation and transpiration by grasses (where they grow) occur, as a rule, in the upper

0.5 m; only during exceptionally dry periods, when there is no available moisture left in this layer, do losses extend to the second half meter of the soil. Therefore, the amount of water taken up by the plantation from the 0-50 cm layer was

calculated from the difference between the total transpiration losses of the plantation and moisture losses from the 50 to 200 cm layer, and in case the latter exceeded the total losses by transpiration, this excess was accredited to evaporation and transpiration by the grass vegetation from the 50 to 100 cm layer. This occurred in plot 4, where, as a result of thinning, evaporation increased and thick grass developed, which was absent in the other plots.

After thinning, the uptake of moisture by the plantation from the 100 to 200 cm layer remained at the same level, that from the 50 to 100 cm layer decreased only in plot 4 in 1955, and that from the 0 to 50 cm layer decreased in plot 4 in 1954 and in all the plots in 1955 (Table 5). Thus, thinning caused a decrease in the moisture uptake by the plantation from the upper soil horizons.

The role of various horizons in the supply of moisture depends on meteorological conditions. If the 100 to 200 cm layer supplies from 40% to 75% of water for the transpiration of the tree stand during years with a warm and moist winter when the soil is wetted to a depth of 2 m (1955) at the beginning of the growing period, in years when it is wetted no deeper than 1 m (1954), this layer practically does not participate in the supply of moisture to the stand.

The results of the study of the dynamics of available moisture are presented in Figure 1. Moisture was classified by availability on the basis of the results of previous investigations (9, 10).

By the winter of 1952-1953 the soil was so dry that the entire upper 2 m of soil did not even contain moderately available moisture. However, ample winter precipitation and frequent warm spells promoted the gradual wetting of the soil, which reached a depth of 2 m by April, whereby the depth of wetting was smaller in the thinned plots than in the control, which was apparently caused by the increased snow and meltwater evaporation after thinning. Transpiration began in the third decade of April. Losses of available moisture were greatest in the upper horizon and decreased with depth, reaching a constant value below 50-60 cm. This year, the second after thinning, moisture was used more slowly in all plots than in the control plot; as a result the period with moderate available moisture in them lengthened by 10-30 days,² which positively affected the growth of the plantations when moisture was deficient. The continuing moisture losses resulted in the complete lack of available moisture in the upper soil horizons in July-August. This zone gradually increased to a depth of 50 cm. Precipitation in September, even though it could not be used by the trees because of the end of the growing season, had a certain positive effect by eliminating the dry zone, which promoted the further wetting of the soil. As a result of the freezing winter of

1953-1954, with little snow, the entire soil profile lacked easily and moderately available moisture until spring snow melting. Spring wetting was shallow (80-110 cm). Ample precipitation in May, 1953, increased the depth of the wet layer another 10 cm, but even though the total supply of moisture to the soil was small, and the contents of available moisture depleted very early in the first three plots; only in plot 4 did moderately available moisture remain 15 days longer. Even not readily available moisture was depleted in the layer from 0-60 cm in the first 3 plots by July 10 and in plot 4 by August 1. Only by the end of August did precipitation wet the soil to a depth of 30-40 cm. During this year the rate of moisture uptake was approximately the same along the entire 2 meters of the profile, which is evidenced by the vertical direction of the isolines of available moisture in Figure 1. Autumn-winter wetting began from mid-October and lasted with small interruptions to the very beginning of the growing period, since the winter of 1954-1955 was mild and wet. The depth of spring wetting reached 2 m everywhere, while the moisture contents were so great that the easily available moisture was depleted only by July 1, and moderately available moisture by July 25, in the first three plots, and by August 5, in plot 4. Thus, after 3 years, thinning had almost no effect on conserving available moisture. In the spring of 1956, an ice crust on the soil surface caused a local redistribution of meltwater along mesorelief elements and the moisture contents at the beginning of the growing period were so small that even relatively strong rains (100 mm) were not able to create stable reserves of moderately available moisture in the first 3 plots. The rate of moisture losses during the growing period was uniform with depth in 1955 and 1956.

Thus, the study of the dynamics of available moisture in the soil showed that there is a deficiency of available moisture every year under 20-year-old forest plantations on watersheds in the dry steppe. The contents of easily and moderately available moisture are completely depleted, as a rule, at the beginning of the warm period (July) and a plantation is forced to use the scant reserves of not easily available moisture at the end of this period, reducing transpiration to 15-20 mm/month, which has a very unfavorable effect on its growth. Thinning prolongs the availability of available moisture to the plantations, especially during the first year. During the following years the development of the leaf mass of the remaining trees restores the possibilities of transpiration, and moderately available moisture in plots 2 and 3 is preserved only a few days longer than in the non-thinned plot. In plot 4 it is retained somewhat longer.

As mentioned earlier, grass vegetation (unproductive moisture consumer) overtakes severely thinned plantations, evaporation increases, and the absence of lateral shading by the crowns of the main tree type — oak — strongly reduces its height increment. Therefore, a certain optimum thinning should be practiced, under which the foregoing negative effects would not take place, whereas the positive effects would be sufficiently fully represented.

² Here and further we assume that the period of moisture availability of one or the other category of availability lasts to the moment when this moisture disappears completely from the entire upper 2 m of the soil profile.

The foregoing data indicate that conditions created in plot 3, where 50% of the ash and 50% of the acacia were cleared, correspond best to optimum thinning.

Conclusions

1. The thinning of oak-ash plantations on a watershed in the dry steppe resulted in a change of the soil moisture regime. Even though the total moisture losses from the soil remained at the former level during the growing period, the transpiration losses of the tree stand decreased and evaporation from the soil surface and transpiration by grass vegetation increased.

2. As a result of thinning the moisture uptake of the tree stand from the upper soil layer decreased, while the uptake from deeper layers (below 0.5 m) hardly changed.

3. Available soil moisture is used more slowly under thinned plantations than under dense ones.

4. Even though transpiration losses by the tree stand decreased, the amount of moisture used on the average on the transpiration of a single tree increased. There is a high positive correlation of ($r = +0.83 \pm 0.15$) between transpiration losses of a single tree and the wood increment.

5. Regular thinning is required to improve the moisture availability to plantations on a watershed in the dry steppe. However, the degree of thinning should not be too severe to prevent grass vegetation from taking over and avoid an excessive increase of evaporation from the soil surface.

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QUANTITATIVE CHANGES IN ORGANIC MATTER IN ORDINARY CHERNOZEM UNDER DIFFERENT AGRICULTURAL USES

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We studied the accumulation and decomposition of the roots of annual and perennial field crops, as well as the dynamics of humus under these crops from 1948-1954 in an ordinary, shallow, coarse clay chernozem at the "Uryupinskoye" educational farm of the Stalingrad Agricultural Institute. Perennial grasses under the cover of spring wheat were sown here in 1947 and 1948, while spring wheat was sown over the perennial grasses (plowed in spring and late autumn) on the inverted sod, on 3-year old-abandoned land, and on old-cultivated land. The experimental sowings were located along a strip of shrubs for snow retention. Table 1 gives the results of top yields for the period from 1948-1950 (5). The yield of spring wheat tops in the flowering stage was 51.7 cntn/ha and that of hay on the 3-year old abandoned land was only 6.4 cntn/ha. When pure sainfoin was sown it gave considerably higher yields than alfalfa and Agropyrum.

Data on the roots and stubble are given in Table 2. They show that the roots and stubble of winter rye during the flowering stage in the 0-20 cm layer was the least of all crops (23.5 cntn/ha).

The amount of roots and stubble of spring wheat in the milk-wax stage was 33.3 cntn/ha in 1949. The average amount of roots under alfalfa and sainfoin during the first year of use (second year of existence) was 47.7 cntn/ha. During the second year of use (third year of existence) the root mass under perennial grasses was 64.8 cntn/ha, i. e., increased by only 17.1 cntn/ha. But during this period a certain un-assessable amount of roots died and decomposed (Table 3).

Three months after the harvest of annual crops, i. e., in late autumn, when micro-biological processes in the soil die out because of low temperature, the amount of root and stubble residues was 25% of their amount before these crops were harvested. Let us note that the autumn of 1948 was wet, so that the decomposition of organic residues could also have taken place during the autumn. The process is less intense during a dry autumn.

Thus, the widespread belief that 2 weeks after the dying down of annual field crops their roots decompose and root mineralization products form (2) has not been confirmed by our observations.

To study the dynamics of the accumulation and decomposition of humus we took mixed soil samples 20-times from under grasses and in old-cultivated land, and 10 times in old-abandoned land from a depth of 0-20 cm.

The old-cultivated land contained 6.29% humus in the layer from 0-20 cm in 1947. After 4 years of use the humus content in the same layer under the grasses increased from 6.29% to an average of up to 7.0% (Table 4).

There was more humus under sainfoin (pure) during the fourth year of use than under the other grasses and grass mixtures, or 7.11% (mixed soil samples for humus determination "under grasses" were taken from: alfalfa, sainfoin, alfalfa + Agropyrum, and sainfoin + Agropyrum).

The great accumulation of humus under a pure sowing of legume (sainfoin), as compared to a grass-legume mixture, is the result not only of the fact that sainfoin developed better (Table 1), but also that its roots are richer in nitrogen than are the roots of sainfoin. Tyurin (10) says that the formation of humus is closely related to the nitrogen content in the roots of plants and its source of supply to the roots: "The formation and accumulation of humus in soils is determined by the magnitude of nitrogen accumulation."

The humus content under natural abandoned land increased by 0.94% during a period of 12-16 years, i. e., by only slightly more than under sainfoin in 4 years. Table 4 also gives data on the increment of humus as compared with the old-cultivated land. This increment was 66.4 cntn/ha under grasses during the second year of use. It follows from Table 4 that the soil must receive 166.0 cntn/ha of dry organic matter in order that the humus content in it increased by 0.31%, as it occurred in our experiment under grasses in the second year of use. At the same time, the root mass under grasses in the second year of use amounts to 64.8 cntn/ha, i. e., 2.5 times smaller than the quantity required in order that the humus content of the soil increases by 0.31% with a humification coefficient of 0.4.

Thus, if we assume that the humification coefficient is 0.4 (4), then 2-3 times more root residues must participate in the foregoing increment of humus than was assessed at any

Table 1

Yield of field crop tops, cntr/ha on air-dry basis

Crop	Hay yield, cntr/ha			Total yield after 3 years of use	Average for 1 year of use
	Years of use				
	1	2	3		
Spring wheat in the flowering stage, 1950	—	—	—	—	51,7
3-year-old abandoned land	—	—	6,4	—	6,4
Alfalfa	21,3	21,1	8,7	51,1	17,0
Sainfoin	31,9	37,7	23,2	92,8	30,9
<u>Agropyrum</u>	—	17,1	15,4	32,5	16,2
Lucerne + <u>Agropyrum</u>	22,3	25,6	13,2	61,6	20,4
Sainfoin + <u>Agropyrum</u>	26,7	27,3	17,2	71,2	23,7

Note: Comma represents decimal point.

Table 2

Root and stubble^a of various crops (in the layer from 0-20 cm), cntr/ha on air-dry basis

Crop	Years of observation			
	1948	1949	1950	1951
Winter rye in the flowering stage	23,5	—	—	—
Spring wheat in the milk stage	—	33,3	—	—
Alfalfa	42,4	67,1	80,8	56,1
Sainfoin	53,0	62,6	87,2	64,6
Alfalfa — Agropyrum	—	56,3	75,5	84,8
Sainfoin — Agropyrum	—	60,1	81,6	89,7
2-year-old abandoned land	—	—	26,0	—
4-year-old abandoned land	—	—	—	44,0
Old layland	75,2	109,7	70,0	127,2

^aThe stubble was cut several cm (5-7) above the tillering node.

Table 3

Dynamics of the decomposition of root and stubble residues under various crops

Crop	Periods of observation	Root and stubble residues	
		In the 0-20 cm layer	% of those pre-served
Winter rye	June 7, 1948	23,5	100
Winter rye stubble	Oct. 20, 1948	6,2	26,4
Spring wheat	July 15, 1948	33,3	100
Spring wheat stubble	Oct. 20, 1948	7,8	23,4
Alfalfa and sainfoin, 2nd year of use, average	July 15, 1949	64,8	100
Grass sod, 2nd year of use, plowed in spring under spring wheat	July 13, 1950	14,2	22,0

Note: Comma represents decimal point.

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Table 4

Dynamics of humus accumulation under perennial grasses

Crop	Year of observation	Humus, % (according to Tyurin) in 0-20 cm layer	Increment of humus against that in old cultivated land		Amount of dry organic matter necessary for humus renewal, cntr/ha ^a
			%	cntr/ha	
Old-cultivated land, 1947	1948	6,29	—	—	—
Grasses, 2nd year of use	1949	6,60	0,31	66,4	166,0
Grasses, 3rd year of use	1950	6,85	0,56	119,8	299,5
Grasses, 4th year of use	1951	7,00	0,71	151,9	379,7
Sainfoin, 4th year of use	1951	7,11	0,82	175,8	439,5
Old-abandoned land (12-16 yrs).	1949-1951	7,23	0,94	201,2	503,0

^aThe roots of the grasses contained 1.63% nitrogen. On the basis of this the coefficient of humification (with 5% nitrogen in the humus) was calculated as 0.32. But the soil receives a certain amount of ammonia and nitrogen oxides with atmospheric precipitation and also as a result of the nitrogen-fixing activity of the *Azotobacter* and other freely living nitrogen-fixing microorganisms. Taking this into account, the humification coefficient was set at 0.4 (4).

Note: Comma represents decimal point.

moment during the life of the plants. The main cause of the foregoing discrepancy is apparently attributable to the fact that during the observations we did not determine the entire amount of forming roots. During the life of plants, fine roots and root hairs form constantly. They die off, humify, and new roots develop. Humus accumulates when aerobic processes are weakened as a result of soil compaction which limits the supply of oxygen.

The humus content in non-fertilized old-

cultivated soil decreased by 0.70% from 1947 to 1951 (Table 5). This value is possibly somewhat too high because of the somewhat diversified soil, but not more than by 0.2%. The plot with the initial old-cultivated land of 1947 was left as abandoned land. The old-cultivated plot of 1951 is located not more than 50 m from the plot of 1947.

According to the data of Dokuchayev (3), the humus content of chernozem under a feather-grass steppe near the village of Krutoye

Table 5

Dynamics of the decomposition and accumulation of humus under old-cultivated land and short-term abandoned land

Profile No.	State of soil cultivation	Date samples were taken	Humus, % (accord. to Tyurin) in 0-20 cm layer
Mixed sample, taken 20 times 116	Old-cultivated land 1947	—	6,29
	Same 1948 under spring wheat	8.VI.1948	6,13
Mixed sample, taken 20 times 2 53	"	25.VI.1951	5,59
	1-year old abandoned land	4.VI.1948	6,29
	"	14.VI.1948	6,19
Mixed sample from Profiles 431 and 439	3-year old abandoned land	26.VI.1950	6,37
Mixed sample from Profiles 17 and 18	4-year old abandoned land	21.VI.1951	6,56

Note: Comma represents decimal point.

(Balashov district, Saratov Government) was 14.85% in 1878 (6).

This value is possibly somewhat excessive because of the method of sample preparation and the method of humus determination, but not more than by 2%.¹ In 1933 we were able to take several soil profiles in the vicinity of this spot. The humus content was 8%-9%. Thus during a period of about 55 years the humus content of the old-cultivated land decreased by about 4%-5% as compared to virgin land, the decrease averaging 0.10% a year.

The main cause for the decrease in humus is the fact that when growing annual crops without perennial legumes the nitrogen content of the soil decreases because it is removed with the harvest of grain crops, a fact which was pointed out by Sokolov (8).

Nitrogen is contained in the soil primarily in the organic form; its content in humus is about 5%, i. e., 1/20 of the humus, as established by P. A. Kostychev.

Therefore, a loss of nitrogen occurs at the same time as the humus content decreases, as was pointed out by Tyurin (10, 11), whereby each part of nitrogen removed from the soil with the harvest of field crops corresponds to a 20-fold loss in the amount of humus.

In addition to the foregoing cause, a decrease in humus content results also from intense soil aeration because of deep annual cultivation (10).

But if we add the required amount of nutrients in the form of fertilizers (taking into account the foregoing three natural sources of nitrogen supply to the soil and also the contents of phosphorus and potassium) which would compensate for their removal in harvests and partly serve for the development of the root system, then the potential fertility of the soil during the growing of annual crops would increase only as a result of the humification of roots and stubble residues.

It has been proved lately by investigations made by the Soil Institute of the Academy of Sciences of the USSR (9) that when manure is added systematically to the soil when growing annual crops the humus content of the soil and, consequently, its potential fertility not only do not decrease, but increase. This is substantiated by the long-term data of a number of experimental institutions both in our country and abroad (10). Such a phenomenon takes place not only in the chernozem zone (data from the Kuznits and Sumi experiment stations, and also according to our observations [6]), but even in the podzolic zone (Dolgoprud experiment station, K. A. Timiryazev Agricultural Academy, etc.).

Investigations (7) show that the humus content in the soil increases not only from the systematic application of manure, but also

from the application of high amounts of mineral fertilizers during the growing of annual crops. In the plot on 4-year old abandoned land, located between grass plots, the humus content increased by 0.27% as compared to the old-cultivated land of 1947. The abandoned land was not mowed, but partially used as pasture in the autumn. The fact that the tops were not removed and the soil was not cultivated is apparently the reason why humus accumulated under this short-termed abandoned land. In this case the additional nitrogen necessary for the formation and accumulation of humus was supplied to the soil from the air in the form of ammonia and nitrogen oxides by rains, as well as by the nitrogen-fixing bacteria.

As we can see from Table 6, the humus content under grasses after the second year of use was 6.60%, and that under spring wheat after sod, 6.63%. The humus content decreased by 0.10% (6.53%) under wheat inverted sod.

The humus content under spring wheat on inverted sainfoin sod was 6.55%, and that in 3-year old abandoned land, 6.49% in 1952 and 6.41% in 1954 (in the fifth year of plowing). Consequently, there is no noticeable increase in humus content during the first year after the grass sod is plowed in the spring; in the following years, however, when the perennial grass sod is plowed annually under spring wheat, there is a systematic decrease in humus content. Thus, after 5 years of plowing the humus content decreased about 0.20%.

A similar picture was observed by us when grass was plowed in late autumn after 3 year's use. Thus, in 1950 the humus content under sainfoin after 3 years of use was 6.93%, under mixed grasses it was 6.85%, under spring wheat after sainfoin sod plowed in late autumn it was 6.98%, under mixed grasses it was 6.92%, and under inverted sainfoin it was 6.89% in 1952 and 6.74% in 1954, the fourth year of plowing.

Thus, when annual crops are sown over plowed grass sod the humus content decreases (for reasons mentioned earlier) in the same way as it decreases when these crops are sown on old-cultivated lands. But this process is weaker in this case, probably because of the humification of the root remains of perennial grasses which takes place at the same time.

It must be especially emphasized that when sod is plowed a gradual mineralization of the humus occurs, depending on the time of plowing. This makes it possible to plow grass sod, or virgin land, as well as old-abandoned land early without fear of sharply lowering soil fertility in 1 year. It must be noted that even in earlier days certain agriculturists and experimental institutions of the Southeast determined by their experiments (summarized by Avdonin [1]) that the early plowing of grass sod ensures a high crop yield, while in areas with a sufficiently moist autumn it is possible to use grass sod effectively for sowing winter crops.

Conclusions

1. Accumulation of roots under natural short-

¹Humus was determined by Dokuchayev by the Gustavson method without removing the roots from the soil samples.

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Table 6

Dynamics of humus decomposition after spring plowing of grass sod after two years of use

Crop	Year of observat.	Humus, % (according to Tyurin)	Newly formed humus		Decomposed humus
			%	cntr/ha	
Old-cultivated land	1947	6,29	—	—	—
Grasses and grass mixtures, 2nd year of use	1949	6,60	0,31	74,4	—
Spring wheat after sod	1950	6,63	0,34	81,6	—
Same after inverted sod	1951	6,53	0,24	57,6	0,10
Same, after inverted sainfoin sod	1951	6,55	0,26	62,4	—
Same, after 3-year old sainfoin abdn. land	1952	6,49	0,20	48,0	0,06
5th year of plowing of sainfoin sod	1954	6,41	0,12	28,8	0,08

Note: Comma represents decimal point.

termed abandoned land in shallow ordinary chernozem is much slower than under perennial grasses.

Three months after the harvest of annual crops and until late autumn a considerable amount of the root residues from these crops is preserved in the soil.

2. The humus content of the soil under perennial grasses increases already during the life of the grasses.

An increase in humus also takes place under short-termed abandoned land (if it is not harvested), which is the result of the humification of the residues not only of perennial, but also of annual vegetation. The accumulation of humus under short-termed and old abandoned land is considerably slower than under perennial grass sowings, provided they develop well.

3. Calculations indicate that in order to create the observed increase in humus 2-3 times more root residues must participate than the amount of roots assessed in the soil during one or the other period of life of the plants. The main reason for this discrepancy is the constant formation of fine roots and root hairs and their dying off and humification during the life of the plants.

4. There is no accumulation of humus in the soil after the grass sod is plowed, unless fertilizers are added.

The humus formed under perennial grasses or under abandoned land and virgin land is subject to gradual mineralization under plowing, independent of the time of plowing (late autumn or spring).

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EFFECT OF MOLYBDENUM ON PLANT DEVELOPMENT ON SOD-PODZOLIC SOIL AND RED EARTHS

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The positive effect of molybdenum on plant growth was noted as early as 1913-1914 by Chirikov (14). The effect of molybdenum on plants was not investigated for many years and only since the 1930's was it subjected to a systematic study.

The experiments of Bortels (20) and Dmitriyev (4) established the positive effect of molybdenum on leguminous plants. The positive effect of molybdenum on the yield of clover hay and seed was determined in the experiments of Vinogradova and Drobkov (3), Yakovleva and Skvortsov (17), Peterburgskiy (10), Nelyudov (9), and others. Kedrov-Zikhman (5) noted an increase in the root and seed yield of kok-saghyz after the addition of molybdenum. In the experiments of Ratner and Burkin (11) superphosphate, enriched with molybdenum, had a positive effect on the yield of clover and increased the protein content in the hay.

A great number of works is devoted to the determination of the participation of molybdenum in microbiological soil processes and its effect on the fixation of atmospheric nitrogen. In the experiments of Fedorov (13) the addition of molybdenum at a concentration of 0.001 m to the nutrient medium increased the fixation of nitrogen by 74% as compared to the control. The positive effect of molybdenum on the development of pea nodules was noted in the experiments of Bobko and Savvina (2), Nelyudov (9), Vinogradova (3), and others. Matushvil (7) believes that molybdenum is necessary to the normal life activity of *Azotobacter chroococcum*. In his experiments the addition of molybdenum increased the fixation of nitrogen by 600%-700% as compared to the control. The fixation of nitrogen by the nodule bacteria of pod-bearing plants, as shown in the work of Moshkova (8), occurs only in the presence of a certain amount of molybdenum in the soil. The literature also mentions changes in the outer appearance of nodules in the presence of molybdenum in the soil. Blomfield (21) notes that large nodules on the roots of plants provided with molybdenum have a pink coloration as compared to the gray color of nodules on the roots of plants not having received molybdenum. He explains the change in the color of the nodules by the increased life activity of nodule bacteria.

Many papers of foreign authors point to the positive effect of molybdenum on the yield not only of legumes, but other plant families. Thus, the experiments of Davies (22), Mulder (27), Lobb (24), and others show that molybdenum is necessary to higher non-leguminous plants. The investigations of Spencer and Wood (31), Rubins (30), Agarwala and Hewitt (18), and others showed that a deficiency of molybdenum in plants disturbs the protein exchange. Anderson (1) points out that molybdenum is necessary for microorganisms fixing atmospheric nitrogen and also to the exchange process in plants. Molybdenum fertilizers are widely used in a number of foreign countries, especially in Australia, to increase the quality of pastures and improve their grass stand.

Molybdenum is not always contained in the soil in a soluble form and its total content does not indicate its degree of availability to plants. According to the data of A. P. Vinogradov, the content of molybdenum in soils varies from $1.5 \times 10^{-4}\%$ to $1.2 \times 10^{-3}\%$, and averages $2.6 \times 10^{-4}\%$.

The differing availability of molybdenum to plants depends on a number of conditions. Certain authors relate the uptake of molybdenum by plants to the soil reaction. Kedrov-Zikhman (5), Robinson (29), Martschell and Wallin (25), Stockdill (32), Yakovleva (16) and others point out that the availability of molybdenum to plants on acid sod-podzolic soils depends a great deal on liming. Molybdenum becomes more mobile and more easily available to plants under the influence of liming and, therefore, the requirement of molybdenum fertilizers for soils decreases on liming. To prove his point Kedrov-Zikhman presents the data given in Table 1. A number of scientists, including Walker (32), Kline (23), Shkol'nik (15), and others came to the conclusion that liming can be replaced by the addition of molybdenum. Thus, in the experiments of Kline it was noted that the yield of pasture grasses increased after the addition of molybdenum the same way it did after the addition of 1 ton of lime. Stockdill obtained a positive plant reaction to molybdenum in his experiments on soil with a pH of 4.8-6.8; the best results were obtained by him at a pH of 6.0-6.6. In the experiments of Barshad (19) the content of water-soluble molybdenum in the soil

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Table 1

Effect of liming on the availability of molybdenum compounds in the soil and the molybdenum uptake by clover (field experiment from 1948-1949 at Ust'ye)^a

Experimental treatment	Content of water-soluble molybdenum compounds, mg/kg of dry soil	Molybdenum content in clover mg/kg of dry substance		
		In the vegetative organs	In seeds	In roots
PK	0,0050	0,77	2,34	1,50
PK + lime	0,0075	1,09	4,23	2,29
PK + Mo, 3,0 kg/ha	0,0300	—	12,42	—
PK + lime + Mo, 3,0 kg/ha	0,0400	15,22	18,56	29,03

^aExperimental station of the Belorussian Agricultural Scientific-Research Institute.

Note: Comma represents decimal point.

increased as the reaction increased to a pH of 8.0. A good effect was obtained by using molybdenum and lime together. However, the problem of the effect of molybdenum on acid and limed soils cannot be considered as fully clarified and work must be continued in this direction.

The problem of the effect of molybdenum in relation to the availability of phosphorous fertilizers in the soil is of no lesser interest. There is mention in the literature of the effectiveness of molybdenum against a background of large amounts of phosphorus. Thus, Yakovleva (16) notes that "when adding molybdenum, various levels of phosphate nutrition have a great effect on the carbon-protein metabolism of clover." Stockdill (32) and McLachlan (26) showed that the reaction to molybdenum is weak where no phosphorus is added. A good effect was obtained from molybdenum in the experiments of Ratner (11) when superphosphate was added. Walker (33) also points to a

relationship in the effect of phosphorus and molybdenum on the growth and development of clover. Possingham (28) presents data on the influence of molybdenum on the phosphorous exchange and the distribution of phosphorus in tomato plants grown in water cultures.

From this brief literature review we can see that the problem of the effect of molybdenum on plants is of great practical importance.

The object of our investigation was to trace the effect and residual effect of molybdenum on the development of legumes (clover and pea), and also of corn, depending on the reaction of the soil and the amount of phosphorus and, in certain experiments, nitrogen added. We also took into account the influence of molybdenum on the growth of nodule bacteria. The pot experiments were made with 2 soils: the medium clay loam sod-podzolic soil of the Dolgoprud Agricultural-Chemical Experiment Station and the red earths from Anaseuli, Georgian SSR.

Table 2

Chemical characteristics of the soils

Acidity, meq/100 g of soil			pH KCl	P ₂ O ₅		Adsorbed cations, meq		% humus	Total	
Ex-changeable	Al	Hydro-lytic		Total %	Available mg/100	Ca	Mg		N. %	Mo, mg/kg
Medium clay loam sod-podzolic soil										
1,93	1,88	3,63	4,30	0,08	5,97 ^a	6,7	1,3	1,75	0,14	1,4
Red earth										
4,43	4,30	10,57 ^b	3,96	0,13	1,84 ^c	—	—	5,58	—	—

^aAccording to Kirsanov; ^bDisregarding the coefficient 1.75; ^c1% citric acid.

Note: Comma represents decimal point.

The agricultural-chemical characteristics of the soils are given in Table 2, from which we can see that the sod-podzolic soil used by us is only slightly cultivated, poor in available phosphoric acid (as determined by the Kirsanov method), needs liming, and contains a considerable amount of mobile aluminum. We conducted long-term experiments in order to study the effect of molybdenum on soils of various degrees of deficiency in this element.

Experiment on Sod-Podzolic Soil

The experiment on medium clay loam sod-podzolic soil was carried out for 3 years with clover. The effect of molybdenum was studied against a background of potassium and phosphorous fertilization without liming and against a background of lime. The pot experiments were accompanied by an analysis of the plants and laboratory investigations. The experiments



Fig. 1. - Effect of molybdenum on clover development on medium clay loam sod-podzolic soil without lime (A).

1 - P_1K ; 2 - $P_1K + Mo$; 3 - P_4K ; 4 - $P_4K + Mo$.

Same against a background of lime (B)

1 - $CaCO_3$; 2 - $CaCO_3 + Mo$; 3 - $CaCO_3 + P_1K$; 4 - $CaCO_3 + P_1K + Mo$; 5 - $CaCO_3 + P_4K$; 6 - $CaCO_3 + P_4K + Mo$.

were made in glass pots containing 3 kg of absolutely dry soil each. Lime was added once at a rate of 1.0 hydrolytic acidity at the beginning of the experiment, while phosphorus and potassium were added annually. The first year 0.75 g of potassium (K_2O) were added per pot, while the second and third year it was added in the form of potassium sulfate at a rate of 0.5 g per pot. Phosphorus was added at a rate of 0.25 g and 1.0 g P_2O_5 per pot annually in the form of calcium monophosphate. Molybdenum was added once at the beginning of the experiment at a rate of 5 mg/kg of soil in the form of ammonium molybdate. The experiment was conducted at optimum moisture, equal to 60% of full moisture capacity, and replicated twice. We determined the total nitrogen, phosphorus, potassium, and molybdenum in clover. Nitrogen was determined by the Kjeldahl method; phosphorous, by igniting the dry plant material with calcium acetate and then by the Denizhe method; potassium, by the spectral method; and molybdenum by the Vinogradova method using a photocolorimeter.

The first year clover developed normally under all treatments. Phosphorous-potassium fertilizers had a weaker effect than lime. Lime caused a twofold increase in the yield of clover as compared to the control. Molybdenum had a positive effect on the development of clover, which we can see clearly from Figure 1-A, B. The clover had more flower heads in the experiment with molybdenum than the control.

To determine the residual effect of molybdenum we kept the pots with the soil and, after adding phosphorus and potassium, sowed clover in them. The second year clover developed weakly in the pot without lime. A positive effect was obtained from molybdenum only against a background of lime (Fig. 2). The third year clover developed poorly even against a background of lime. Yield and analytical data for the three years of action of molybdenum are given in Table 3.

Data show the positive effect of molybdenum on the yield of clover. The yield of clover tops

over molybdenum against a background of lime was higher than in the controls. The effectiveness of molybdenum against a background of lime decreased somewhat even though the absolute yield increased. Various amounts of phosphorus had little effect on the effectiveness of molybdenum in this experiment. As mentioned earlier, during the second year the plants developed poorly against a background of lime and the hay yield was low. Molybdenum had no effect whatsoever against the background of low clover yield without lime. Clover developed normally against a background of lime and molybdenum had a positive effect, increasing the yield of hay and, especially, seeds. In the third year of the experiment we took account not only of the top yield, but also of the entire dry roots. Data for the third year of the experiment show a sharp decrease in top yield and a complete absence of clover seeds for all experimental treatments. However, in spite of the sharp decrease in clover yield, the positive effect of molybdenum was quite noticeable against a background of lime. The assessment of the roots, also showed the positive effect of molybdenum on the development of clover roots; this is very essential if we consider that the degree of soil enrichment with nitrogen by legumes is determined by the state of development and the mass of their roots.

Analytical data (Table 4) show that molybdenum has a positive effect on the nitrogen uptake of plants; the nitrogen content in the clover tops increased in the first, second, and third year of the effect of molybdenum. The positive effect of molybdenum on the accumulation of nitrogen in the hay of legumes is often mentioned in the literature. Molybdenum had a noticeable effect on the uptake of phosphorus by plants against a limed background; the molybdenum content in the clover hay increased in all the experimental treatments where it was added.

The second experiment with medium clay loam sod-podzolic soil was made against a background of various amounts of lime, added at a rate of 0.25; 0.5; 1.0; and 1.5 hydrolytic

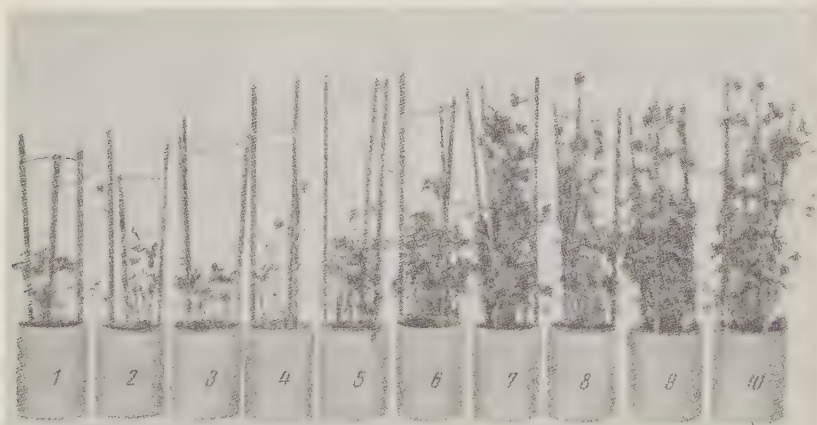


Fig. 2. - Residual effect of molybdenum on clover development on medium clay loam sod-podzolic soil.

Table 3
Influence of molybdenum on clover yield on medium clay loam sod-podzolic soil

Experimental treatment	Effect of molybdenum										Residual effect of molybdenum									
	Yield					Hay yield					Yield					Hay yield				
	Total, g		Seed, mg			N		P ₂ O ₅			Total, g		Seed, mg			N		P ₂ O ₅		
			%	mg	mg/kg	%	mg	%	mg	mg/kg			%	mg	mg/kg	%	mg	%	mg	mg
P ₁ K	8,95	Not detd.	2,0	177	0,5	44	3,6	322	1,7	0,0152	4,90	40	2,0	101	0,7	34	0,8	0,0043	28	0,5
Same + Mo	14,70	"	2,5	370	0,5	73	3,4	500	6,5	0,095	4,98	40	2,4	122	0,7	37	3,4	0,0163	50	0,6
P ₄ K	11,30	"	2,4	276	0,7	83	3,7	423	1,8	0,020	4,06	120	2,1	84	1,8	73	—	—	2,42	0,3
Same + Mo	15,85	160	2,5	394	0,6	100	3,5	554	6,7	0,106	4,67	170	2,1	97	2,0	92	—	—	2,80	0,4
CaCO ₃ (background) 1.0	17,82	180	2,6	463	0,4	85	0,8	151	4,0	0,071	9,50	210	2,4	232	0,5	46	2,5	0,0233	2,71	0,4
hydrolytic acidity	18,65	130	2,6	490	0,4	82	0,9	168	15,1	0,281	11,86	240	2,3	269	0,3	37	8,0	0,0943	17	0,6
Same + Mo	23,90	180	2,3	543	0,5	119	2,4	578	4,2	0,100	25,58	1270	2,4	601	0,4	107	2,4	0,0617	81	0,9
CaCO ₃ + P ₁ K	22,45	150	2,5	563	0,5	112	2,5	550	16,2	0,363	24,77	1590	2,6	555	0,5	138	7,9	0,2369	67	1,2
Same + Mo	20,37	460	2,5	507	0,6	121	2,7	550	4,3	0,087	25,07	1360	2,4	604	0,6	150	—	—	6,80	1,0
CaCO ₃ + P ₄ K	22,02	170	2,5	546	0,5	118	2,8	605	16,4	0,036	27,86	2360	2,4	671	0,5	145	—	—	7,40	1,2
Same + Mo	1,05	—	—	—	—	—	—	—	—	—	0,70	—	—	—	—	—	—	—	0,19	—

Note: Comma represents decimal point.

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Table 4

Influence of molybdenum on the nitrogen content in clover hay medium clay loam sod-podzolic soil

Experimental treatment	First year's experiment				Second year's experiment			
	Without lime		With lime		Without lime		With lime	
	N		N		N		N	
	%	mg	%	mg	%	mg	%	mg
Without fertilizers	—	—	2,60	463	—	—	2,45	232
Same + Mo	—	—	2,63	490	—	—	2,27	269
PK ₁	1,98	177	2,27	543	2,08	101	2,35	601
Same + Mo	2,52	370	2,51	563	2,44	122	2,55	764
P ₄ K	2,45	276	2,49	507	2,08	84	2,41	604
Same + Mo	2,48	394	2,48	546	2,08	97	2,41	671

Note: Comma represents decimal point.

acidity. The fertilizers used were: 0.5 g of phosphorus per pot, 0.75 g K₂O per pot, and 5 mg of molybdenum per kg of soil. The experimental conditions were the same as before. Yield and analytical data are presented in Table 5.

The results of this experiment, as those of the preceding one, showed a sharp increase in the yield of clover when lime was added,

whereby the total yield increased as the amount of lime was increased. Molybdenum without lime did not ensure the normal growth of clover. In all cases the increment as a result of molybdenum was considerably lower than that from lime. Only the addition of lime together with molybdenum to acid soil resulted in a high yield of clover hay and seeds. All this is well illustrated in Figure 3. As in the preceding experiment, the addition of molybdenum

Table 5

Influence of molybdenum on clover yield with various amounts of lime on medium clay loam sod-podzolic soil

Experimental treatment	Effect of molybdenum				Residual effect of molybdenum			
	Yield		In the hay		Yield		In the hay	
	Total, g	Seed, mg	N		Total, g	Seed, mg	N	
			%	mg			%	mg
PK — background	3,47	—	2,17	75	4,45	0,86	1,66	73
PK + Mo	6,35	220	2,26	143	4,41	0,69	1,56	69
PK + CaCO ₃ 0.25 hydrolytic acidity	11,27	200	2,66	299	7,35	1,81	2,30	169
Same + Mo	16,20	200	2,35	380	6,73	1,26	2,39	160
PK + CaCO ₃ 0.5 hydrolytic acidity	21,25	250	2,58	548	8,97	1,86	2,32	208
Same + Mo	25,45	290	2,40	610	8,72	1,49	2,23	194
PK + CaCO ₃ 1.0 hydrolytic acidity	25,11	550	2,44	612	12,12	1,71	2,33	284
Same + Mo	26,29	830	2,32	609	12,70	1,71	2,41	306
PK + CaCO ₃ 1.5 hydrolytic acidity	22,09	440	2,67	589	11,0	1,64	2,58	284
Same + Mo	25,00	830	2,29	572	10,80	1,36	2,28	246
+ m	0,90	—	—	—	1,07	—	—	—

Note: Comma represents decimal point.

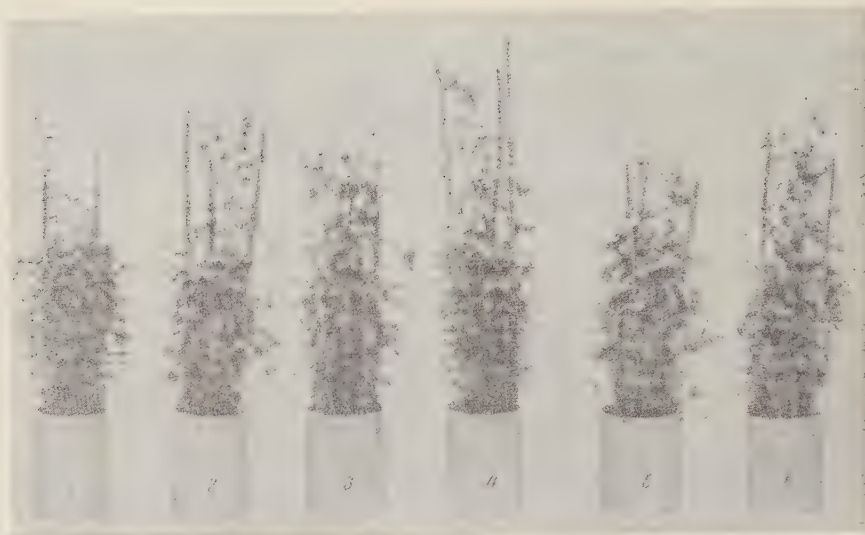


Fig. 3. - Effect of molybdenum on clover development on medium clay loam sod-podzolic soil with various amounts of lime.

1 - CaCO_3 0.5 hydrolytic acidity + PK; 2 - same, + PK + Mo; 3 - CaCO_3 1.0 hydrolytic acidity + PK; 4 - same, + PK + Mo; 5 - CaCO_3 1.5 hydrolytic acidity + PK; 6 - same, + PK + Mo.

increased the nitrogen content in clover hay.

To determine the effect of molybdenum on the formation of tubercles we made sand culture experiments with peas. We studied the effect of molybdenum over the complete nutrient mixture of Hellriegel in pots filled with 1.0 kg of sand. Molybdenum was added at a rate of 5 mg/kg of sand. The experiment included treatments with a double amount of nitrogen and a triple amount of phosphorus. The experiment was made in 2 groups: the seeds of the plants in the first group were not inoculated with nodule bacteria while the seeds in the second group were. The peas developed normally under all experimental treatments, but in those where molybdenum was used the plants had a greater color, were higher, and had more pods. This was found both in the case of seeds inoculated with nodule bacteria and those which were not (Fig. 4-A). The peas were harvested in the wax stage. After the harvest the total nitrogen, the weight of the roots, and the number and weight of the nodules were determined. Yield and analytical data are presented in Table 6.

From Table 6 we can see that molybdenum had a positive effect on the yield of peas and the number of nodules. With molybdenum the nodules were larger and were located mostly on the central tap root. Without molybdenum there were more nodules, but they were smaller. According to the data of Anderson (1), a deficiency of molybdenum limits the development of nodule bacteria and thus reduces nitrogen fixation by them, which apparently reflects on the growth, development, and yield of legumes. This relationship was rather clear in our ex-

periments with various degrees of nitrogen availability to the plants. With the first amount of nitrogen (0.25 g per pot), when the seeds were not inoculated with nodule bacteria, the addition of molybdenum increased the yield of the dry mass of the peas by 33%, while with a larger amount of nitrogen (0.5 g per pot), the yield increment was 50%. The inoculation of seeds with nodule bacteria in itself improves the nitrogen nutrition of plants, as a result of which the yield of peas increased considerably with the first amount of nitrogen. The increase of the amount of nitrogen increased the yield of peas and the weight of the nodules almost twice. With the first amount of nitrogen molybdenum produced an increase in yield of 28% and an increase in the weight of the nodules of 45%. With the second amount of nitrogen the addition of molybdenum had little effect on yield and produced only an 11% increment in the weight of the nodules. With a triple amount of phosphorus the addition of molybdenum produced a 35% increase in the yield of the dry mass of peas and in the weight of the nodules. The nitrogen content of plants increased only when the seeds were inoculated with nodule bacteria.

The positive effect of molybdenum on the growth and development of nodule bacteria is well known from the literature. The results of our experiments are not an exception in this respect, they only confirm the similar nature of the effect of molybdenum in them. Our experiment showed noticeable differences in root development with and without molybdenum. The dry weight of the roots increased in all cases when molybdenum was added.

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Table 6

Effect of molybdenum on development of peas with various amounts of nitrogen and phosphorus (sand culture)

Experimental treatment	Seeds not inoculated with nodule bacteria					Seeds inoculated with nodule bacteria						
	Dry mass yield, g	Increment %	Weight of roots, g	N %	N in the dry mass, mg	Dry mass yield, g	Increment %	Weight of roots, g	N. %	N in the dry mass, mg	Weight of nodules, mg	Increment %
Hellriegel's nutrient mix- ture (N—0,25)	1,62	—	0,72	2,11	34	5,20	—	0,57	3,24	189	110	—
" N—0,25+Mo	2,15	33	0,84	1,87	40	6,67	28	1,06	3,21	214	160	45
" N—0,5	3,47	—	1,04	1,81	62	9,97	—	0,75	2,50	201	180	—
" N—0,5+Mo	5,19	50	1,35	1,90	97	10,23	12	1,26	2,56	309	200	11
" P ₂ O ₅ triple amt.	3,58	—	0,87	3,18	171	7,09	—	0,79	2,77	196	170	—
" " + Mo	4,85	—	1,00	2,66	107	8,45	—	1,01	3,02	255	230	35
" + m	0,17	—	—	—	—	0,31	—	—	—	—	—	—

Note: Comma represents decimal point.

Experiments with Red Earth

We studied the effect of molybdenum on the yield of corn with various amounts of phosphorus for 2 years. Fertilizers were added annually, including 1.0 g of nitrogen and potassium per pot with 2.1 kg of soil in the form of ammonium nitrate and potassium sulfate. Nitrogen was added in 2 stages: 0.50 g of nitrogen when the pots were filled and 0.5 g of nitrogen as dressing; phosphorus was added in the form of calcium monophosphate at rates per pot of 0.5 g, 2.0 g, and 4.0 g P₂O₅ the first year and 2.0 g, 4.0 g, and 8.0 g P₂O₅ in the second year. Molybdenum was added at a rate of 5 mg/kg of soil only once at the beginning of the experiment. The experimental conditions were the same as before. We determined the total nitrogen and phosphorus in the yield of

corn. Yield and analytical data for this experiment are presented in Table 7.

Corn reacted sharply to the addition of phosphorous fertilizers on red earth; the total dry mass yield increased as the amount of phosphorus was increased. During the first year molybdenum had little effect on the yield of corn, causing a small increase only where 4 g P₂O₅ were added per pot. To obtain a better picture of the effect of molybdenum in relation to phosphorus, the amounts of phosphorus, the amounts of phosphorus were increased the second year to 8 g P₂O₅ per pot. The positive effect of molybdenum was more pronounced the second year (Fig. 4-B). The yield increment as a result of molybdenum when phosphorus was added the second time at a rate of 2 g P₂O₅ was 37%. Molybdenum

Table 7

Influence of molybdenum on corn yield on red earth with various amounts of phosphorus

Fertilizers	Effect of molybdenum						Effect of molybdenum					
	Amount of P ₂ O ₅	Total wt. of dry mass, g	In the yield				Amount of P ₂ O ₅	Total wt. of dry mass, g	In the yield			
			N		P ₂ O ₅				N		P ₂ O ₅	
			%	mg	%	mg			%	mg	%	mg
NK	—	2,10	3,20	67	0,192	4	—	1,09	2,55	27	0,27	2,9
Same + Mo	—	1,95	3,96	77	0,175	3	—	1,19	2,39	28	0,31	3,6
NP ₁ K	0,5	3,60	3,93	141	0,210	7,5	2,0	29,3	2,62	768	0,44	128
Same + Mo	0,5	4,40	3,96	174	0,200	9	2,0	40,2	2,40	963	0,37	148
NP ₃ K	2,0	33,40	1,99	659	0,235	78	4,0	15,40	2,68	411	1,16	178
Same + Mo	2,0	33,40	2,16	721	0,250	83	4,0	22,60	2,48	560	1,01	228
NP ₃ K	4,0	46,30	2,33	1078	0,470	217	8,0	14,6	2,78	398	1,78	258
Same + Mo	4,0	50,40	2,21	1113	0,470	237	8,0	11,82	2,91	344	2,05	242
± m	±	0,88	—	—	—	—	±	0,92	—	—	—	—

Note: Comma represents decimal point.

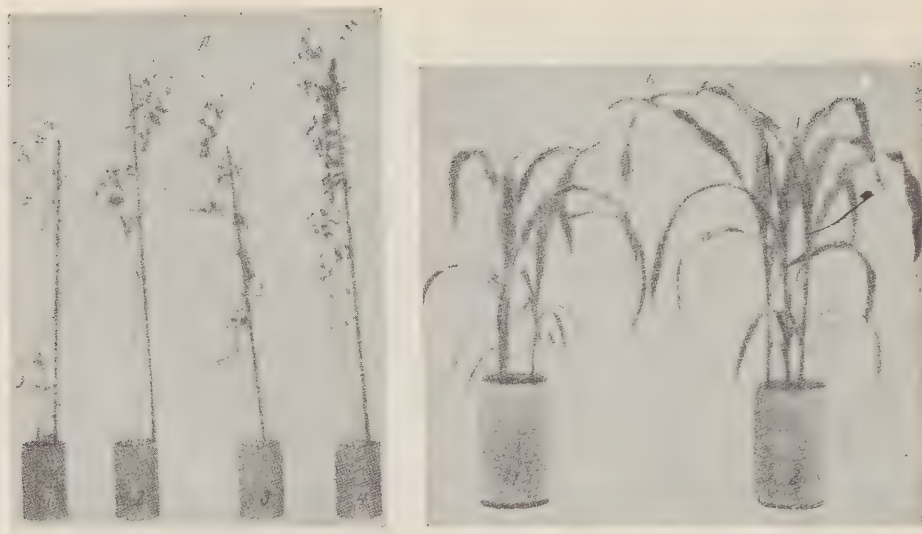


Fig. 4. - Effect of molybdenum on the development of pea. Sand culture. Seeds not inoculated with nodule bacteria (A).

1 - without Mo; 2 - Mo. Seeds inoculated with nodule bacteria; 3 - without Mo; 4 - Mo. Effect of molybdenum on the development of corn on red earths (B). 1 - NPK; 2 - NPK + Mo.

increased the nitrogen and phosphorous content in the plants.

Conclusions

1. In pot experiments molybdenum had a positive effect on the development of clover on medium clay loam sod-podzolic soil.

2. The positive effect of molybdenum was reflected both against a background of lime and without lime. The best effect was obtained from a combination of lime and molybdenum.

3. We established a relation between the effect of molybdenum and the availability of nitrogen and phosphorus in the soil and plants. The effectiveness of molybdenum decreased with increasing amounts of nitrogen and increased with increasing amounts of phosphorus.

4. The number of nodules on the roots of legumes increases under the influence of molybdenum. This promotes a considerable increase of the fixation of atmospheric nitrogen and, consequently, a better supply of nitrogen to legumes.

5. The positive effect of molybdenum on corn on red earth appeared as a residual effect after a second application of phosphorous.

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METHODS

METHODS OF STUDYING ORGANIC MATTER IN PEAT-BOG SOILS

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Existing methods of determining the quantitative content and qualitative composition of humus were worked out for mineral soils with a low content of organic matter (a maximum of 10%-15%), which in these soils is more or less homogeneous, amorphous, and evenly distributed throughout the mineral mass of soil horizons. Peat soils are characterized by a high content of organic matter, which is heterogeneous, coarsely disperse, and of a specific composition, especially when the degree of decomposition of the peat is low. Therefore, the methods developed for mineral soils are unsuitable for peat soils and require modification.

Below we will describe methods developed or modified by us for studying organic matter in peat soils. Their substantiation and the results of their use on various soils are described in a previous paper (2). Some of these methods may find application in the analysis not only of peat, but also of other substances containing a high amount of organic matter, such as forest litter, plant materials, compost, etc.

I. Sulfur-Chromium Method for Simultaneously Determining C and N

This method is based on the method of the French soil scientist-chemist Anstett (6) who suggested it for rapidly determining the C:N ratio in soils. The principle of this method consists in oxidizing a sample of substance containing from 50-100 mg of organic C, with a sulfur-chromium mixture of 3.0 N CrO_3 and an H_2SO_4 : H_2O ratio of 3:2. The original method of Anstett did not satisfy us because the oxidation technique described by him was not safe for the analyst and did not give faultlessly accurate results. Anstett recommended the addition of 20 ml of a 17% solution of CrO_3 to the sample, and then the addition of 30 ml of strong H_2SO_4 . In doing this there is an immediate strong heating of the oxidizing mixture and a violent decomposition of the organic matter, which leads to the spilling of the contents of the flask, sometimes accompanied by an explosion. In order to avoid this

we first prepare a large supply of a cooling mixture from 2 parts of a 12% solution of CrO_3 and 1 part of concentrated H_2SO_4 and add 31 ml of this mixture to the sample, and then we add 20 ml of concentrated H_2SO_4 . When doing this there is only a very weak, completely safe heating of the mixture. We decreased the CrO_3 concentration in the oxidizing mixture somewhat on purpose in order to increase the accuracy of this volumetric method. The description of our modification follows.

Reagents Required

1. Sulfur-chromium mixture. Two parts of a 12% solution of CrO_3 are mixed with one part H_2SO_4 of a specific gravity of 1.84. The mixture is cooled to room temperature.
2. Concentrated H_2SO_4 .
3. 0.2 N Mohr's salt.
4. Phenylanthranilic acid as indicator. 0.2 g of Na_2CO_3 are dissolved in 100 ml of water on warming and then 0.2 g of phenylanthranilic acid.
5. 50% solution of NaOH.
6. Granulated zinc or zinc powder.
7. Titrated solution of 0.01 N H_2SO_4 .
8. Titrated solution of 0.01 N NaOH.
9. Indicator: 100 ml of methyl red + 50 ml methylene blue.

Samples for analysis are selected depending on their ash content, namely:

ash, %	sample, g
<10	0.20
10-25	0.20-0.25
25-50	0.25-0.40
50-75	0.40-0.75

A sample of air-dry peat or other plant material (passed through a sieve with openings 0.25 mm in diameter) is weighed on an analytical balance and placed in a conical flask of

¹The work was done at the laboratory of Academician I. V. Tyurin.

heat-resistant glass. In order that the oxidizing mixture boils evenly, a little (at the end of a knife) ignited pumice or loess soil is added to the sample. Then exactly 30 ml of the sulfur-chromium mixture (reagent 1) from a buret with a glass stopcock and 20 ml of concentrated H_2SO_4 from another buret, or a 25 ml graduated cylinder, are added to the mixture. The amount of H_2SO_4 added does not necessarily have to be highly accurate, but the amount of the titrated solution of the sulfur-chromium mixture must. The chromium mixture must always be evenly and slowly poured from the buret. For this we recommend the use of a stopwatch: the 30 ml of the mixture must be poured from the buret in 3 min, regulating the speed of fall of the drops.

Then the flask is covered with a small funnel to act as a cooler, its contents are carefully stirred, and when the violent decomposition of the organic matter has ceased the flask is placed on a warm Eternit plate or a sand bath where its contents are brought to boiling and are boiled slowly for exactly 5 min on the stopwatch or an hourglass. The bubbling of carbon dioxide, which takes place before boiling should not be mistaken for boiling. The boiling of the mixture begins when large gas bubbles appear at its surface.

When cooled, the contents of the flask are carefully transferred by means of water from the wash-bottle into a 250 ml² volumetric flask. After complete cooling, the liquid is brought to volume and mixed thoroughly. From this volume of liquid 2 samples of exactly 25 ml are taken with a pipette for titration with Mohr's salt (with phenylanthranilic acid) for the determination of C by oxidation and two 5 ml samples for distilling ammonia and determining N. Ammonia is distilled with 25 ml of 50% NaOH and a piece of granulated zinc or zinc powder. Twenty-five mls of 0.01 N H_2SO_4 are poured into a receiving flask. The excess acid is titrated with 0.01 N NaOH with the methyl red + methyl blue indicator. If the content of N is low in the substance analyzed, it is better to take 100 ml of the solution, instead of 50 ml, and 50 ml of 50% NaOH for distilling NH_3 .

A blank test for determining the ratio between the sulfur-chromium mixture and Mohr's salt on the one hand and the 0.01 N H_2SO_4 and 0.01 N NaOH solutions when determining N, on the other hand, is run under exactly the same conditions.

The results of C and N determinations are calculated in percent of the dry weight of the substance analyzed. The calculated N content is multiplied by a coefficient of 1.03, taking into account that in this method an average of 97% of N is mineralized.

II. Sulfur-Chromium Method of Determining the Degree of Internal Oxidation and Approximate Elementary Composition of Organic Matter in Substances Containing Little Ash

²Or 500 ml flash, whereby the volume of the samples is doubled for the determination of C and N.

This method differs from the previous one in that the oxidation of exactly the same sample of analyzed material with exactly the same amount of oxidizer is achieved not in an ordinary flask, but in the Knop apparatus in the presence of the catalyzer Ag_2SO_4 (especially in the case of peat soils which contain non-readily oxidizable organic matter of the type of bitumens). We obtain the following data as a result of all the determinations:

CCO_2 , i. e., C as determined by the weighing method from the weight increment of CO_2 ,

CO_2 , i. e., C as determined by oxidation and N, by the distillation of ammonia.

On the basis of these data the degree of internal oxidation (d) of the organic substance analyzed is calculated by the formula:

$$\pm d\% = \frac{(CCO_2 - CO_2) \times 100}{CCO_2} \quad (3, 4)$$

and its approximate elementary composition is determined by the method proposed by Stance and Nemec (7) and used by Tyurin and Ponomareva (4). To calculate the latter, the analytical data for CCO_2 , CO_2 and N are expressed in percent of the water-free and salt-free organic substance, as determined from the ignition loss (allowing for CO_2 carbonates in calcareous peat).

To simplify the calculations we suggest that the following formulas be used for determining the percentual content of H in the organic substance analyzed:

1. Organic substance with a normal degree of oxidation

$$(C_n:H_{2m}:O_m), \text{ when } CCO_2 = CO_2, \%H = 11.11 - 0.11C + 0.08N.$$

where C and N are expressed in percent of water-free and salt-free organic substance.

2. Organic substance with a high degree of oxidation

$$(C_n:H_{2m}:O_{(m+y)}), \text{ when } CCO_2 > CO_2,$$

or an organic substance with a low degree of oxidation

$$(C_n:H_{2m}:O_{(m-y)}), \text{ when } CCO_2 < CO_2,$$

$$\%H = 11.11 - 0.41CCO_2 + 0.30CO_2 + 0.08N.$$

In all cases the percentual content of O in the organic substances is found from the difference: $\%O = 100 - (CCO_2 + H + N)$.

Under thorough analysis the mathematical method of determining elementary composition is accurate for substances with a low ash content. The accuracy of the method of determining organic matter in samples with a high ash content from the ignition loss is lower because of the effect of chemically bound water, and the data on elementary composition according to C and N may be somewhat too low, while those according to H and O, somewhat too high.

Below we give a detailed description of the method adopted by us for simultaneously determining CCO_2 , CO_2 , and N in the Knop apparatus for carbonate-free soils and plant materials.

A sample of the substance to be analyzed is weighed on an analytical balance and placed in a flask for combustion by the Knop apparatus. A small amount of ignited pumice and 0.2-0.5 g of Ag_2SO_4 for a catalyzer are added to the flask for even boiling. The flask with the dry sample is connected to the Knop apparatus and air is drawn through it for 30 min to remove CO_2 and NH_3 .³ By this time the absorption tubes must be weighed and exactly 30 ml of the sulfur-chromium mixture (reagent 1) must be placed in a small glass (about 50 ml capacity) by pouring it slowly from the buret (for 3 min).

After the Knop apparatus is cleaned of CO_2 and NH_3 air, 2 absorption tubes with ascarite (or soda lime) and calcium chloride are connected to it. A small, ordinary funnel is inserted temporarily into the separatory funnel so that its neck remains clean and 30 ml of the sulfur-chromium mixture are poured through it from the glass, and then 20 ml of concentrated H_2SO_4 are poured by means of a graduated cylinder. Then the ordinary funnel is removed and placed in a glass, while the separatory funnel is sealed with a stopper, connecting it to the purification system. By carefully drawing air through the apparatus, the oxidizing solutions are drawn successively into the flask for combustion and the stopcock of the separatory funnel is closed. Thereafter the apparatus is disconnected from the pump or aspirator and the flask is carefully heated to the boiling point on a gas burner or an electric plate with an asbestos net. The oxidizing mixture is boiled for exactly 5 min by the stopwatch or hourglass. If the boiling is done on an electric plate, it must be turned off 5 min after boiling begins and a thick layer of asbestos or some other heat-insulating material must immediately be placed under the flask. Then air, purified of CO_2 and NH_3 , is drawn through the apparatus for 40-50 min and the apparatus is connected to the absorption tubes. The tubes are weighed 15-20 min later when their temperature has become equal to that of the surrounding air. Organic carbon (CCO_2) is calculated from the weight increment of the tubes, multiplying the weight of carbon dioxide by 3/11.

Further, the oxidizing mixture must be transferred without loss into a volumetric flask. To do this the residues of the chromium mixture in the glass and funnel, through which it was poured into the Knop apparatus, as well as those on the walls of the Knop apparatus and in the tube of the separatory funnel, are washed with water from the wash-bottle into the 250 ml volumetric flask. The collected oxidizing mixture is quantitatively trans-

ferred with water into the same volumetric flask, which is brought to volume with water after it has cooled. After thorough mixing, 2 samples of 25 ml each are taken from the volumetric flask for titration with Mohr's salt and 2 samples of 50 ml each, for the distillation of ammonia. Because 98% of N become mineralized in this method as a result of the use of Ag_2SO_4 as catalyzer, a correction coefficient of 1.02 must be used for calculating the true content of N.

A blank test for determining the ratios between the chromium mixture and Mohr's salt and between the 0.01 N H_2SO_4 and 0.01 N NaOH solutions is run under strictly similar conditions in the Knop apparatus. The proper conduct of the blank test for the determination of the ratio between the chromium mixture and Mohr's salt is of great importance. Investigations showed that about 2.5% of the amount of CrO_3 taken decompose in the process of self-reduction when the H_2SO_4 to H_2O ratio in the oxidizing mixture is 1.5. Therefore, one of the obligatory conditions of the blank test is boiling, whereby pumice is used instead of soil (the addition of Ag_2SO_4 is unnecessary). The blank test must be run at least 2 times. The solution obtained in the volumetric flask during the blank test may serve for several days for determining the control ratio between the chromium mixture and Mohr's salt. Sometimes, when determining the blank ratio, a blank test can be made with an exact sample of some individual organic compound, preferably of a normal degree of oxidation (such as glucose) and a known carbon content. When conducting a blank test in such a manner that about half of the amount of CrO_3 taken is lost during the oxidation of the organic substance, as in the actual test, there is no possibility for error owing to the differential degree of self-reduction of CrO_3 in the actual and blank test. To calculate the number of mls of Mohr's salt used for the blank titration, one must add the number of mls of Mohr's salt used for the titration of the excess CrO_3 in the sample taken for titration with the number of mls of Mohr's salt equivalent to the content of oxidized carbon in the sample (1 ml of 0.2 N Mohr's salt corresponds to 0.0006 g of C).

Until now we examined the determination of the CCO_2 , CO_2 and N content in non-calcareous soils and plant materials. The carbonates contained in the soil have no effect on the determination of carbon by oxidation. However, in cases when the content of organic carbon is determined by the weighing method in the Knop apparatus, the carbonates must be destroyed beforehand. To do this, a sample of air-dry peat, depending on the assumed content of organic carbon, is placed in a dry flask for combustion in the Knop apparatus, and 20 ml of 10% H_2SO_4 are added to it, stirring gently. After a considerable portion of the CO_2 carbonates is removed, the contents of the flask are boiled moderately for 10 min on an electric plate with an asbestos net or a sand plate for the complete decomposition of the carbonates. After the carbonates are decomposed and the contents of the flask are cooled, 0.2-0.5 g of silver sulfate and pumice are added to the flask and it is connected to the condenser of the Knop apparatus (from which the absorption

³ To remove CO_2 and NH_3 from the air the outer adsorption system must consist of drexel with sulfuric acid, drexel with 50% NaOH and a column with soda lime or ascarite. The column is connected to the separatory funnel of the Knop flask.

tubes are removed), and then air is drawn through the apparatus for 40-50 min. Thereafter the absorption tubes are connected to the apparatus and first 30 ml of the sulfur-chromium mixture (reagent 1) and then 50 ml of strong H_2SO_4 are poured into the flask through the separatory funnel. As a result, the ratio between sulfuric acid and water in the oxidizing mixture is 3:2. The further procedure for the combustion of the organic substance is the same as the one described previously for carbonate-free soils.

If we need to find out not only the content of organic C, but also that of the CO_2 carbonates, they must be decomposed directly in the Knop apparatus with connected absorption tubes, which must be replaced by new ones before igniting organic C with the sulfur-chromium solution. Ag_2SO_4 is added before the sulfur-chromium mixture is admixed, at which time the flask and the condenser must be disconnected. When the amount of carbonates in the soil is small, they are best determined by the weighing method in the Knop apparatus from a single, large sample. Then the content of organic C can be calculated from the difference between the amount of C in the soil, as determined by the composition of the carbonates, and the C of the carbonates themselves.

III. Scheme and Method of Investigating the Fractional-Group Composition of Organic Matter in Peat-Bog Soils⁴

In order to unify the methods of studying the fractional-group composition of organic matter of all soils without exception, the scheme is based on the method of Tyurin (5, 1) for mineral soils, supplemented by certain special determinations taking into account the specificity of the organic matter in peat soils. The present method provides for the determination of both humified as well as non-humified organic substances in peat, when possible. A standard ratio of 1:100 between peat and the solvents is used in the method (both for acid and alkaline extracts). The duration of the infusion of peat with the solvents is 20 hr. The fractions are determined from C and N, whereby the results of the analysis are expressed in percent of absolutely dry soil and in percent of the total content of organic C and N in it. The method permits analysis of 10-12 soil samples at one time.

Analytical Procedure

1. Removal of the bitumen fraction. A 10- to 20-g sample of air-dry peat, passed through a sieve with openings 1 mm in diameter, is extracted in the Soxhlet apparatus by a 1:1 mixture of alcohol and benzene until all the bitumens are removed. The solvent is evaporated on a water bath and the bitumin residues are dried at a temperature of about 80°C, and weighed. The C content in the bitumens may conditionally be taken as 72%, or it may be determined by the weighing method in the Knop apparatus.

The soil is air dried after extraction until all the alcohol and benzene are removed.

2. Decalcification with 0.1 N H_2SO_4 . A 2.5 g (or 5 g) sample of the extracted and air-dried peat is weighed on an analytical balance, placed in a conical 400 to 500 ml flask, and 250 ml of a 0.1 N H_2SO_4 solution are poured over it. The soil is thoroughly mixed several times during the working day and then left undisturbed overnight. The next day the extract is filtered through a smooth filter, 12-15 cm in diameter, and the remaining soil is washed with water, acidified with H_2SO_4 , until the entire calcium is removed, and then washed with distilled water 2-3 times. The extract, together with the washings, is brought to a certain volume (usually 500 ml) and mixed thoroughly. Its various portions are used to determine: organic C (according to the Tyurin method after neutralization with sodium and carbonate evaporating on steam bath), organic N (according to the Tyurin method), and, if desired, substances after a 2-hr hydrolysis on a water bath with 1.0 N H_2SO_4 . In addition, the mineral composition of the extract can be determined at the same time, for instance, the amount of Ca and Mg in it, which may be considered as no longer exchangeable in non-carbonate peats. Since R_2O_3 must be precipitated before determining Ca and Mg it is easy to determine them in order to be able to judge the content of mobile Fe and Al in peats.

The C content of this organic fraction in peat-bog soils is usually insignificant, but the N content reaches considerable values, especially in slightly decomposed upland peats.

Hydrochloric acid is used for the decalcification of calcareous soils. If the content of CO_2 carbonates in the soil is known, then in order to decompose them their equivalent in 5% HCl is added to the soil sample, while if it is not known, 5% HCl is added in small amounts until effervescence ceases or until the reaction is weakly acid (drop test with methyl red). Then the concentration of free HCl in the solution is brought to 0.1 N. Ca is first washed with water, acidified with HCl, and then with water, and acidified with H_2SO_4 , until Ca and Cl are completely removed.

The content of the given fraction does not have to be determined since C in it is insignificant and it is impossible to determine it by the Tyurin method (in the presence of Cl^-).

3a. 0.1 N NaOH-extract after decalcification. The remainder of the soil after decalcification is washed without drying from the filter and into the same infusion flask with a 0.1 N solution of NaOH (200 ml for a 2.5 g sample and 400 ml for a 5 g sample), measured in a clean wash-bottle. But first, a funnel, 10-12 cm in diameter, with a short and wide neck is inserted into the flask, which is later thoroughly washed into the same flask with the remainder of the measured amount of alkali. At the end the rest of the alkali is poured on the filter to wash the humic solutions from it, which were absorbed by the filter paper. Then the filter is thrown away and the alkaline solution with the soil is mixed several times and left undisturbed until the next day.

⁴ This analytical procedure, up to step 4-5, can be recommended for mineral soils.

The next day a quarter of the alkali (i. e., 50 or 100 ml) from the saturated Na_2SO_4 solution is added to the flask to accelerate filtration, the solutions are mixed, then one waits until the colloids flocculate (10-15 min). The contents of the flask are mixed again immediately before filtration and filtered through a loose, smooth filter, 15-16 cm in diameter. The remainder of the soil in the flask and in the funnel is washed with a 1%-2% solution of Na_2SO_4 until the leachate is completely, or almost completely, clear. The filtration of alkaline extracts from peat-bog soils is very slow, but nevertheless, with the small samples used in the analytical scheme, it is usually finished by the end of the day; the next day the washing is done. Only in rare cases is filtration with washing prolonged to 3 days.

The alkaline filtrate together with the washings is brought to a volume of 500 or 1000 ml and thoroughly mixed. Its separate portions are used to determine the total C and N according to the Tyurin method, or the Anstett method in our modification, and the C and N of humic acids after their precipitation with sulfate acid (the concentration of free H_2SO_4 must approximately correspond to 0.1 N). The C and N of fulvic acids can be calculated by difference.

3b. 0.1 N NaOH-extract from non-decalcified soil. The 0.1 N NaOH extract is obtained and analyzed in the same manner from the same sample of non-decalcified soil, i. e., immediately after its extraction with the alcohol and benzene mixture and air-drying. The data of this determination, corresponding to free or R_2O_3 -bound humic and fulvic acids, are calculated from the total data of the analysis of the acid (0.1 N H_2SO_4) extract and the following alkaline (0.1 N NaOH) extract. The difference obtained corresponds to the content of humic and fulvic acids bound with calcium, or those which are more resistant to dissolution in alkali. The soil, remaining after the direct alkaline extract, is thrown away and not used in the further analysis. The further operations are conducted with soil remaining after the alkaline extract from decalcified soil.

4. 0.02 N NaOH extract.⁵ During the same day the soil remaining after operation 3a is washed without drying into the same infusion flask with a 0.02 N solution of NaOH (200 or 400 ml), measured in a clean washer. Washing proceeds more rapidly if the 0.02 N NaOH solution is previously heated to 70°-80°C. Then the flask is covered with watch glass and placed in a violently boiling water bath for 6 hr, counting from the time when the contents of the flask are warm enough. This extract is filtered and the remainder is washed on the following day in the same way as described previously. The extract with the washings is also brought to 500 or 1000 ml and used for the same determinations as the preceding alkaline extract. This operation dissolves a fraction of humic substances, apparently of the type of humin, which is very characteristic of strongly decomposed peats.

5. Hydrolysis with 1.0 N H_2SO_4 . The remainder of the soil is washed without drying into the same flask with a 1.0 N H_2SO_4 solution (250 ml), measured in a clean washer. It is also better to heat the solution to 70°-80°C. The flask is covered with watch glass and placed in a violently boiling water bath, or a Koch boiler, for 2 hr. The extract is filtered through a smooth paper filter and washed with cold water until the wash water is clear and sulfuric acid is completely removed.

The filtrate and the washings are brought to a volume of 500 ml, from which separate samples are taken for the determination of C and N, and, if necessary (in poorly decomposed peat), reducing substances according to the Bertrand method. The latter are expressed in carbon for comparison with the total C of this fraction. In well-humified peat the C in reducing substances is sometimes higher than the total C of the hydrolyzed fraction. This indicates that the major component of the fraction is not carbohydrate, but something else (usually rich in nitrogen).

6. Hydrolysis with 80% H_2SO_4 . The soil remaining after hydrolysis with the 1.0 N solution of H_2SO_4 is washed from the filter with hot water into a porcelain dish, 6-8 cm in diameter, and the water is removed by evaporating on a water bath, whereby the dish is lifted from the bath at the moment when the material is still slightly moist. It should not be completely dry, because it becomes very hard and leathery and cannot be ground in the mortar and does not disperse in 80% H_2SO_4 . When it is removed from the bath in a slightly moist state, it is easily dispersed in 80% H_2SO_4 when stirred with a glass rod with a flat, pestle-like end. The 18 ml of 80% H_2SO_4 are poured directly into the porcelain dish and stirred with its contents during the 2.5 hr of its infusion. Then the contents of the dish are washed with a washer bottle with a measured amount of water (250 ml) into a conical flask, which is then covered with watch glass and placed into the Koch boiler for 5 hrs, or into a violently boiling water bath. The extract is filtered through the outer glass filter (Schott funnel 2-3), the entire residue is placed on the filter, washed with water until the complete removal of sulfuric acid, dried, and weighed.

The filtrate and the washings are brought to a definite volume (500 ml), from which individual samples are taken for the determination of C, N, and, if necessary, reducing substances by the Bertrand method.

7. Insoluble and non-hydrolyzable residue. The C and N in the residue can be calculated from the difference between the total C and N in the peat and the sum of C and N of all the fractions, or determined by the modified Anstett method. In the latter case a correction must be introduced for the weight decrease of the residue as compared to the initial sample. The C:N ratio is best determined directly, since if it is calculated by difference it may deviate strongly from the actual value because of the errors in the many individual determinations of C and N. Because of the unavoidable substance losses during the removal of various fractions, the value of the residue could be somewhat too

⁵ Depending on the objective of the analysis, a simplified scheme and analytical procedure may be used.

Table 1

Results of determination of the composition of organic matter according to the fractionation scheme described, % of total C

Peats	Sample No.	Bitu- mens	Humic acids				Fulvic acids				Hydrolyzable with H ₂ SO ₄		Sum of soluble sub- stances	Ratio of ha + faa carbon	«K»
			1	2	3	Sum	1a	1+2	3	Sum	1,0 n	80%			
Slightly decomposed	72	6,5	1,0	0,5	3,2	4,7	1,3	5,9	5,0	12,2	9,7	22,8	55,9	0,5	4
	99	5,0	3,1	0,0	2,8	5,9	0,5	5,9	7,5	13,9	10,3	37,1	72,2	0,4	5
	73	6,4	5,5	1,3	4,7	11,5	0,7	6,0	8,5	15,2	9,8	33,7	76,6	0,6	8
Strongly decomposed	81	7,7	23,9	2,5	13,8	40,2	1,4	16,9	6,6	24,9	2,9	2,7	78,4	11,6	88
	64	5,9	15,7	9,0	20,6	45,2	1,1	10,6	6,0	17,7	3,1	1,8	74,5	12,8	72
	108	2,4	4,6	14,1	16,1	34,8	2,6	18,9	9,5	31,0	2,7	2,5	73,4	12,7	82
	111	4,4	7,8	11,2	20,2	39,2	1,4	18,8	7,1	27,3	2,5	2,1	75,5	14,5	80
	112	3,6	5,8	19,0	15,7	40,5	2,1	17,6	6,5	26,2	1,9	1,9	74,1	17,6	88
Kursk chernozem	2	—	6,4	23,0	7,6	37,0	2,8	11,9	8,0	22,7	4,8	3,9	68,4	7,0	84

Fractions: 1a — soluble in 0.1 N H_2SO_4 ; 1 — directly in 0.1 N NaOH; 2 — additionally in 0.1 N NaOH after decalcification; 3 — soluble in 0.02 N NaOH when heated for 6 hr in a water bath.

^aHumic acids + fulvic acids

Note: Comma represents decimal point.

low and, consequently, also the data for C and N in the residue, while the values of C and N would remain unaffected.

Since the organic matter in soils and, especially, peat contains 10 times more C than N, the data for the fractional composition are more accurate for C than for N. Therefore it is better to proceed in the following manner when determining C and N in the residue: calculate the C in the residue from the difference between the total content of C in peat and the sum of C in all the fractions; determine the C:N ratio in the residue directly, i.e., by the first sulfur-chromium method described earlier, and by dividing the value of C, calculated by difference, by the actual C:N ratio obtained, we will find the N content in the residue.

The nature of organic substances in the insoluble and non-hydrolyzable residue can be determined from the C:N ratio, which varies for various peats from 20 to 2000, depending on their degree of humification. A narrow C:N ratio indicates the predominantly humic composition of the residue, while a wide ratio indicates a predominantly lignin composition. In addition, the insoluble and non-hydrolyzable peat residue can be studied under the microscope and, if necessary, subject to supplementary alkaline hydrolysis. But if such detailed investigations should be made, the initial peat sample must be increased to 5 g or even 10 g.

IV. Rapid Analytical Method for Determining the Degree of Humification of the Organic Matter in Peat

The method is based on the fact that in the humified organic matter of soils, including peat bog soils, nitrogen is chemically combined with humic substances, whereas in unchanged plant residues it forms part of the proteins, amino-acids, and other substances of primary vegetative nature. The latter are capable of entering a 0.1 N NaOH extract, which is used as the main solvent of humic substances. Therefore, the substances removed by the 0.1 N NaOH extract cannot always be considered as humified. By empirical means we found that the ratio between C and N in a 0.1 N NaOH extract of humified peats and chernozem almost coincided with that in peat or chernozem. In slightly humified peats the C to N ratio in a 0.1 N NaOH extract is much lower than in peats as a whole, since predominantly the products of decomposition of proteinaceous substances are removed in this extract, while nitrogen-free substances (hemicellulose, cellulose, etc.) are only slightly removed in an alkaline solution. The more the C:N ratio in a 0.1 N NaOH extract deviates of the C:N ratio of peat as a whole, the lesser is the degree of humification of the substance removed in the 0.1 N NaOH extract. Because of this we propose the following formula for determining the degree of humification of the organic matter in peat soils:

$$K = \frac{C}{a:b} \cdot 2,$$

where K is a conditional coefficient of the humification of peat;

C is the carbon of the 0.1 N NaOH extract after decalcification in % of the total C in the peat;

a is the C:N ratio in peat;

b is the C:N ratio in the 0.1 N NaOH extract after decalcification.

The constant conditional multiplier 2 is introduced because about half of the humic substances are removed in the 0.1 N NaOH extract; the remaining half is in the form of more stable compounds. The coefficient of humification of the organic matter in peat varied in our investigations from 4 in samples of light-colored sphagnum waste to 88 in black, strongly humified peats.

Table 1 gives the results of the study of the composition of organic matter according to the described scheme and the calculated coefficients of humification "K" for slightly and strongly decomposed peats as compared to chernozem. The results are described in detail in another article by us (2).

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INTENSITY OF NITRIFICATION OF CHERNOZEMS IN RELATION TO THEIR COMPACTNESS

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All mechanical cultivation practices, except rolling, decrease soil compactness. The use of various cultivation tools for weeding, working in plant residues, fertilizers placement, etc. is usually associated with the loosening of the soil to another depth, even though it might not be necessary as far as the state of the plowed field and its compactness are concerned.

The friability of a plowed field does not always indicate favorable conditions. A very friable plowed field is only expedient in regions with favorable moisture conditions, especially during the period of maximum precipitation. Under these conditions, a friable plowed field promotes the better absorption of precipitation, and also the more intense development of biological processes in the soil, and, consequently, the greater accumulation of nutrients in it. However, the great friability of the soil is not retained long here; under the influence of rain it compacts rapidly and often acquires the same structure as before cultivation. Thus, in the experiments of Bondarenko (1), conducted under favorable moisture conditions at the field experiment station of the Timiryazev Agricultural Academy and at the educational farm "Otradnoye," after loosening the soil acquired the same compactness as before, after 7 days in 1952 and 8 days in 1953. Under the foregoing conditions the soil can be kept friable only in a fallow field under systematic loosening.

As far as dry regions are concerned, practice shows that the friability of a plowed field causes rapid drying and, consequently, a decrease in the biological activity of the soil, and conditions for plant nutrition deteriorate. The unfavorable properties of a friable field are well known to agriculturists in dry regions. They are more pronounced, the drier the period during which the field is in a friable state. In these regions the soil is compacted with rollers or other means to prevent or decrease the possible unfavorable effects of a friable field.

As the numerous data of scientific-research institutions and agricultural practice show, the rolling of the soil generally has a positive effect on crop yield. According to our observations (11), the rolling of the soil with heavy, smooth rollers before sowing creates favorable conditions for a uniform seed-bed during sowing to a given depth, improves the water and

temperature regimes of the plowed layer, and promotes a stronger development of the root system and shoot of grain crops and a considerable increase in their yield. The positive effect of compaction on various soil properties was also reported in the works of Tsitronblat (10), Kolyasev (4, 5, 6), Zhuchenkov (3), Skol'zayeva (8), Sinel'nikov (7), and a number of other investigators.

However, there is another opinion in the literature according to which the compaction of the soil has a negative effect on certain of its properties. For instance, in the opinion of Yarovenko (13), compaction has a negative effect on the hydrological properties of the soil, even though, according to his own data, the yield on compacted soil was 15%-20% higher than on the control (not compacted). But this he attributes to the even depth of the seed-bed on sowing and the earlier and good germination of the plants on rolled soil, and not to soil moisture. Negative results were obtained from soil compaction in the experiments of Gadalova (2) when growing corn in pots without bottoms on sod-podzolic soils. But the soils were compacted to a bulk density of up to 1.30-1.37 g/cm³, i. e., such a degree of compaction which, under our conditions, is only found in deep, subplow horizons.

There is now a large amount of scientific and practical material showing the positive effect of soil rolling before and after sowing. But all these materials do not give the necessary idea of the optimum compaction of the plowed horizon, while existing methods of measurement do not allow determination of its quantitative indices. In particular, the role of the varying compactness of a plowed field in determining the nature and intensity of biological processes in individual soil layers is not quite clear; does increased compactness always repress these processes and to what degree does it negatively affect the level of effective soil fertility?

In order to clarify these questions we studied the influence of varying soil compaction on its nitrification capacity and certain other properties from 1956-1958 under laboratory and field conditions. We believe that the intensity of the nitrification process is one of the reliable and sufficiently clear indicators when characterizing the role of varying soil compaction.

This indicator reflects well the conditions of development of biological processes and gives a good idea of the level of nitrogen nutrition — one of the main elements of effective soil fertility.

We studied the influence of varying soil compaction on the intensity of nitrification and other biological processes in an experiment conducted in 600 ml beakers in a thermostat at a temperature of 28° -30°C; loose packing corresponded to a bulk density of 0.90 g/cm³, while tight packing corresponded to 1.20 g/cm³.

The experiment was made on 2 soils with a moisture content of 60% and 30% of full moisture capacity: soil rich in organic matter, taken from the upper 0-10 cm of old abandoned land, and soil relatively poor in organic remains, taken from a fallow area of an old-plowed field. One kilogram of the first soil contained 25.2 g of fresh and semi-decomposed organic residues, while the second contained only 9.6 g, or almost 1/3 as much.

It must be noted that the gradation in the degree of humus compaction (bulk density of 0.9 g/cm³ and 1.2 g/cm³) in the experiment corresponds approximately to the compaction of cultivated and non-cultivated areas under field conditions. True, the bulk density of 1.2 g/cm³, taken for the most compacted soil, is not always found under field conditions, even at the end of the growing season. Thus, the leached chernozem of the Siniiskhozm, which is fall plowed annually, had the following bulk density in the various layers after the wheat harvest:

		1955	1959
In the layer from	0-5 cm	0.99	1.01 g/cm ³
"	7-12 cm	1.12	1.24 "
"	15-20 cm	1.12	1.15 "
"	22-27 cm	1.18	1.24 "

The bulk density of shallow southern chernozems from the sovkhos "Sibiryak," which is located in a very dry steppe area of the Omsk Oblast' (Drobyshev rayon), varies approximately within the same limits. The bulk density of the foregoing horizons of the soil in this sovkhos in 1956 was: 1.05, 1.10, 1.06, and 1.23 g/cm³, respectively, and in 1957 it was: 0.89, 0.98, 1.08, and 1.17 g/cm³, respectively. The upper soil horizons were not very compact in 1957 in the sovkhos as well as in the area where wheat was sown over stubble cultivated to a shallow depth (6-8 cm) with disc harrows for a period of 3 years (without plowing). In this area the bulk density of the soil by layers was: 0.85, 0.99, 1.21, and 1.30 g/cm³, respectively. Only in the deeper layers, which were not touched by disc harrows for several years, was the bulk density of the soil the same as that of the most "compact" soil in our experiment, while in the lowermost, subplow layer (22-27 cm) it was somewhat higher.

The varying degrees of soil compaction found under field conditions would have reflected on its moisture conditions and temperature regime, which in its turn would have affected the intensity, and in certain cases (fine-textured soils with a high moisture content), the direction of development of biological processes in it. In our experiment an optimum soil temperature was always maintained, while moisture was kept at a designed level of 60% of full moisture capacity (which is also optimum for our conditions). Thus, in our experiment we were able to disclose the factors in which we were interested and to evaluate their importance in a "pure" state.

As we know, aeration decreases as soil is compacted, and consequently it is natural to expect a deterioration of conditions for the development of the nitrification process. However, there is apparently no direct relation

Table 1

Decomposition of organic residues in the soil in relation to compactness and moisture content

Soil	Soil moisture, % of full moisture capacity	Bulk density, g/cm ³	Amount of organic residues, g/kg of dry soil			Decomposed organic residues in % after	
			Before composting, May 25, 1956	Following composting after			
				3	6	3	6
				Months			
Old abandoned land	60	0,90	25,2	19,8	8,0	21,4	68,2
Same	60	1,20	25,2	18,2	8,5	27,7	66,2
"	30	0,90	25,2	22,0	9,0	12,6	64,3
"	30	1,20	25,2	19,9	10,7	21,0	57,5
Clean fallow on old-plowland	60	0,90	9,6	8,0	2,3	16,6	76,0
Same	60	1,20	9,6	7,9	3,0	17,7	68,7
"	30	0,90	9,6	9,5	1,9	1,0	80,2
"	30	1,20	9,6	8,4	2,5	12,5	73,9

Note: Comma represents decimal point.

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between the degree of soil compaction and aeration and the process of nitrification in nature, since the intensity of this process also depends to a considerable degree on moisture conditions, soil texture, its content of organic matter, and temperature and other conditions.

We can judge the absence of a direct relation between soil compaction and the intensity of its biological activity from the results of observations on the dynamics of decomposition of organic residues in the soil (Table 1).

The data in Table 1 show that during the first 3 months after the experiment was set up, the decomposition of organic residues in friable soil was not more intense than in more compact soil, even though it was to be expected insofar as during the given period the difference in soil compaction between the treatments studied was closer to that at the beginning of the experiment than at a later period. During the foregoing 3 months less organic residues decomposed in the friable soil, especially when its moisture content was kept at a level of 30% of full moisture capacity, than in compact soil. And only in the 3 following months did a certain advantage of the friable soil appear, as a result of which somewhat more organic residues decomposed in it at the end of the month than in the compact soil. However, the difference in the amount of decomposed organic residues in these soils is so insignificant that it cannot serve as a bases for a negative evaluation of compact soil (with a bulk density of 1.20 g/cm³).

We also made direct determinations of the biological activity of the soil by collecting from a unit area in a set time interval the carbon dioxide released from the soil (according to the method of Shtatnova [12]) 4 and 14 days after the experiment was set up (Table 2).

Table 2 shows that the compaction of the soils to the limits given indicates that it not only did not lower, but increased the intensity of biological processes considerably. The positive effect of compaction manifested itself on soil rich in fresh organic residues (old lay-land) as well as on the considerably less rich

old-plowed soil taken from the fallow area, and not only under an optimum moisture of 60%, but also with a moisture of 30% of full moisture capacity. It is characteristic that compaction had a more pronounced effect in increasing biological activity in soil poor in fresh organic residues (clean fallow) than on the soil from the old-abandoned land, rich in organic matter. Thus, if under optimum moisture conditions the amount of carbon dioxide released from old-abandoned land after 4 and 14 days was 142% and 137% as compared with the amount released under similar conditions from friable soil, that released by clean fallow was 174% and 483%, respectively. Approximately the same relationship between the amount of carbon dioxide released from compacted and friable soil was obtained with a moisture of 30% of full moisture capacity.

Under optimum temperature conditions and the foregoing moisture levels, soil compaction had no negative effect on the intensity of the nitrification process. True, there was a slight lag in the accumulation of nitrate nitrogen during the first period of the experiment (Table 3), but later this difference leveled off and the amount of nitrate nitrogen accumulating in the compacted soil was not less, but in most cases even more than in the friable soil. Without going deeper into these changes, let us note that the intensity of the nitrification process was rather high in the friable and in the compact soil.

Approximately the same results in the study of the nitrification process in relation to soil compactness were obtained by us in an experiment made in 1958 according to a somewhat different scheme. This experiment was made in zinc plated pots of a capacity of 2750 cm³, a height of 16 cm, and a diameter of 14.8 cm. The pots had no bottom, but each had a drip pan into which the pots were placed when the soil in them was composted. The experimental scheme consisted of the following 4 treatments: first — complete packing of the soil, taken as 100%; second — soil compacted to 90% of the first; third — soil compacted to 80% of the first; and fourth — soil compacted to 70% of the first.

Table 2
Amount of CO₂ released from an area of 12.6 cm² in 24 hours, mg

Soil	Soil moisture, % of full moisture capacity	Bulk density, g/cm ³	Amount of CO ₂ in mg after compositing for the dura- tion of	
			4 days	14 days
Old-abandoned land	60	0,90	12,5	14,2
Same	60	1,20	17,7	19,5
"	30	0,90	11,2	9,9
"	30	1,20	13,4	13,4
Clean fallow on old-plowland	60	0,90	3,5	2,4
Same	60	1,20	6,1	11,6
"	30	0,90	0,9	—
"	30	1,20	3,9	6,3

Note: Comma represents decimal point.

Table 3

Amount of nitrate nitrogen, mg/kg of dry soil

Soil	Soil moisture, % of full moisture capacity	Bulk density, g/cm ³	Before com- positing, May 25, 1956	Following compositing after		
				3	6	12
				Months		
Old-abandoned land	60	0,90	8,91	384,4	452,0	858,0
Same	60	1,20	8,91	259,5	441,7	—
"	30	0,90	8,91	178,7	292,7	547,9
"	30	1,20	8,91	136,0	284,5	564,3
Clean fallow on old-plowland	60	0,90	28,1	98,9	193,0	372,7
Same	60	1,20	28,1	81,0	245,1	435,8
"	30	0,90	28,1	93,0	172,4	434,4
"	30	1,20	28,1	92,1	244,4	340,1

Note: Comma represents decimal point.

The compaction of non-cultivated virgin land was taken as 100%. The pots were filled with the non-cultivated virgin soil in situ in the field by placing the pots over soil columns cut beforehand to a diameter slightly larger than the diameter of the pots. The excess soil was cut by the sharp edges of the pots. The pots were thus filled with soil without disturbing its natural structure and compactness.

Before "cutting" and lifting the soil with the first 3 pots from the virgin area, the sod was removed to a depth of 5 cm. Consequently, the pots were filled with soil from the layer 5-21 cm deep. To retain the homogeneity of the soil, the more friable soil was placed in all pots by layers, namely from 5-9 cm, 9-13 cm, 13-17 cm, and 17-21 cm, in the same order as they were under natural conditions.

Therefore, the soil was mixed only within every 4 cm layer. We also assumed that the compactness of all the foregoing layers was the same. When filling the pots, each soil layer was packed by weight in its designed placed, leveled, and tamped to a certain level, marked in advance.

The bulk density of the soil from the non-cultivated virgin land in the first three pots was: 1.16 g/cm³, 1.09 g/cm³, and 1.20 g/cm³, averaging 1.15 g/cm³. The deviations from the average bulk density of the soil in individual pots are small. They do not exceed 4%-6% and did not interfere with the clarification of our problems. There were no deviations in the bulk density of the more loosely packed soil within each experimental treatment. Depending on the design compactness, the bulk

Table 4

Dynamics of nitrate nitrogen in relation to soil compactness, mg/kg of soil, 1958

Date	Packing density, %	Bulk density, g/cm ³	Layers, cm				Average 5-21
			5-9	9-13	13-17	17-21	
June 4	Initial sample		3,4	Trace	None		0,9
June 24	100	1,15	22,3	13,2	11,5	9,2	14,0
Same	90	1,04	13,2	11,9	9,7	6,5	10,3
"	80	0,92	13,5	8,2	8,2	4,8	8,7
"	70	0,81	22,6	12,0	7,2	4,6	11,6
Aug. 6	100	1,15	40,1	24,2	14,2	13,9	23,1
Same	90	1,04	33,0	11,9	10,1	15,4	17,6
"	80	0,92	26,3	15,1	12,9	11,9	16,6
"	70	0,81	23,3	16,6	14,0	9,2	15,8
Sept. 18	100	1,15	51,6	26,0	20,4	18,5	29,1
Same	90	1,04	33,4	26,3	10,1	22,1	22,7
"	80	0,92	71,4	19,7	20,9	17,9	32,5
"	70	0,81	51,7	12,5	20,9	14,7	24,9

Note: Comma represents decimal point.

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density of the soil in the various experimental treatments was: 1.15 g/cm³ for the soil compacted to 100%; 1.04 g/cm³ for that compacted to 90%; 0.92 g/cm³ for that compacted to 80%; and 0.81 g/cm³ for that compacted to 70%.

The soil was composted at room temperature and a moisture content of 30%-35% of the absolutely dry weight, which is about 50%-60% of the full moisture capacity of this soil.

The experiment with composting lasted 3.5 months. As we can see from Table 4, a large amount of nitrate nitrogen accumulated during this period, but much less than in the preceding experiment. This is attributable to the different experimental conditions. In the first case composting was done in a thermostat at a temperature of 28°-30°C, and in the second at a temperature of 18°-20°C and lower. But under these conditions, which are less favorable to the development of the nitrification process, the compactness of the soil had no negative effect. On the contrary, more nitrate nitrogen accumulated in the non-cultivated virgin soil, which was most closely packed, than in the more friable soils. This indicates that the most compact soil, which in this experiment had a bulk density of 1.15 g/cm³, was the most favorable soil for the development of the nitrification process.

It must be noted, however, that even though each soil layer was packed to the same density in the pots, especially in those packed layer by layer, the largest amount of nitrate nitrogen accumulated in the uppermost layer; its content decreasing gradually in the lower-lying layers. Except for a few small deviations, the same was true for pots with the most tightly packed soil (100%) and the most loosely packed soil (70%). Such behavior cannot be explained by the difference in the compaction of the individual layers. This is most probably due to the difference in amount and quality of organic matter at various depths, the different amounts of air oxygen in these layers, and other conditions which require further study and clarification.

We can see from Table 4 that before the experiment was started (June 4), nitrate nitrogen was found in large amounts only in the uppermost layer of the non-cultivated virgin land, which is typical for this type of land. The distribution of nitrate nitrogen is less pronounced in areas with perennial grasses, as

well as in areas under other agricultural uses. This, however, is not associated with the compactness of the soil in the non-cultivated virgin or abandoned land, which, by the way, is not that great in our case (bulk density of the soil, 1.15 g/cm³), but with its air oxygen content and the virgin vegetation permanently growing on it, part of the available forms of nitrogen nutrients forming in it are used.

The foregoing conclusion is confirmed by the results of our observations on the dynamics of nitrate nitrogen in 2 neighboring plots, 4 m² each, on non-cultivated virgin land. When the experiment was started, the 4- to 5 cm thick sod was removed from one of the plots and the plot was systematically kept free of plants. The vegetation in the other plot was left undisturbed. Only traces of nitrate nitrogen or no nitrate nitrogen at all were found in it in the course of 2 years (1958-1959). A noticeable amount of nitrate nitrogen was found after a little more than 1 month in the plot free of vegetation (Table 5).

As we can see from Table 5, the compactness of the non-cultivated virgin land did not interfere with the development of the nitrification process in the soil under field conditions. By the end of autumn 1958, i.e., 3.5 months after the sod was removed from the plot (June 4, 1958), about 40 kg of nitrate nitrogen (converted to ha) accumulated in the plowed layer (0-20 cm). This amount is probably too low, since the area is not large enough (2 x 2 m) and the nutrients accumulating in it are taken up to a certain degree by plants surrounding it. But nevertheless, the data on the course of nitrate nitrogen accumulation confirm rather well the results of laboratory experiments, according to which increased soil compaction does not interfere with the normal development of the nitrification process in it.

The content of phosphoric acid in the soil is associated to a certain degree with the microbiological activity of the soil. Therefore in studying the dynamics of nitrate nitrogen we simultaneously determined the P₂O₅ content in the soil in some of the experiments (in a 0.006 N HCl extract according to the method of Frantson [9]). The results of these determinations are summarized in Table 6. These do not show a sufficiently clear relationship between the degree of soil compaction and the amount of phosphoric acid in it. But these data show without doubt that the amount of

Table 5

Dynamics of nitrate nitrogen in a clean virgin area, mg/kg dry soil

Date of determination	Layers, cm					Date of determination	Layers, cm				
	0-5	5-10	10-20	20-30	Average		0-5	5-10	10-20	20-30	Average
June 20, 1958	Trace		None		Trace	Sept. 18, 1958	13,9	25,4	11,0	Trace	12,6
July 10, 1958	13,1	6,4	6,4	Trace	5,5	May 26, 1959	10,9	9,7	14,9	10,2	11,4
July 20, 1958	12,6	6,4	8,5	2,1	7,4	July 14, 1959	15,4	2,2	1,9	1,3	5,2
Aug. 20, 1958	25,0	11,1	6,7	3,2	11,5	Sept. 30, 1959	3,9	5,3	3,8	8,8	5,4

Note: Comma represents decimal point.

Table 6

Dynamics of P_2O_5 in relation to soil compactness, mg/kg of soil, 1958

Date of determination	Bulk density, g/cm ³	Layers, cm				
		5-9	9-13	13-17	17-21	Average 5-21
June 24	1,15	51,3	36,5	24,0	16,2	32,0
"	1,04	23,4	24,9	17,1	15,1	20,1
"	0,92	22,7	19,6	14,2	14,9	17,8
"	0,81	22,9	22,3	17,1	12,8	17,8
August 6	1,15	75,4	61,2	30,4	18,9	46,5
"	1,04	27,4	25,8	21,3	14,6	22,3
"	0,92	30,5	26,9	18,2	16,0	22,9
"	0,81	34,0	32,8	18,2	12,7	24,4
September 18	1,15	68,5	34,1	23,3	16,0	35,4
"	1,04	32,2	27,3	21,5	14,6	23,9
"	0,92	30,2	25,6	18,2	15,3	22,6
"	0,81	31,0	31,1	19,1	17,9	24,8

Note: Comma represents decimal point.

phosphoric acid was highest at all periods of observation in the most closely packed soil in non-cultivated virgin land. There is also no negative effect of increased soil compaction on the content of phosphoric acid in the other, variously compacted soils.

Thus, the bringing up of the bulk density of the soil to 1,15-1,20 g/cm³, i. e., the compaction of the plowed horizon to the maximum possible degree under our conditions, had a positive effect on the intensity of the nitrification process and the accumulation of nutrients in most of the cases.

It must be noted, however, that the results of laboratory investigations of the influence of soil compaction on nitrification processes in it are also substantiated by the results of observations under field conditions. This was verified to a certain degree by the determination of nitrate nitrogen in soil cultivated in different ways at the "Sibiryak" sovkhov, lo-

cated on shallow southern chernozems in a very arid steppe area of the Omsk Oblast' (Drobyshv rayon).

As we can see from the data in Table 7, the shallow cultivation of stubble with disc harrows to a depth of 6-8 cm in this sovkhov ensured more favorable conditions of nitrogen nutrition in spring as compared to the usual autumn plowing with skim coulters to a depth of not less than 20-22 cm. Such stubble field has, as a rule, a more friable structure in the spring than a harrowed field. As observations show, the higher soil compactness in the harrowed field protects it from the drying effect of spring winds in the open steppe and promotes its better warming, which in turn leads to the higher intensity of the nitrification process, the better development of plants, and their greater yield. Thus, in the past 5 years (1955-1959) the average yield of spring wheat over stubble in the "Sibiryak" sovkhov was 9.3 ctnr/ha over an area of 42010 ha

Table 7

Nitrate nitrogen in an autumn plowed field and harrowed field, kg/ha

Cultivation	May 15, 1957	June 16, 1958	June 20, 1959
In the layer from 0-20 cm			
Autumn plowed to a depth of 20-22 cm	17,7	23,9	3,3
Har. to depth of 6-8 cm	21,1	36,4	12,5
In the layer from 0-60 cm			
Autumn plowed to a depth of 20-22 cm	24,9	34,0	28,1
Har. to depth of 6-8 cm	61,3	36,4	32,4

Note: Comma represents decimal point.

(total for 5 years), while over spring harrowed areas of 13840 ha it was 13.0 cnt/ha, or 40% more.

In the neighboring "Tselinnyy" sovkhos (Russko-Polyanskiy rayon) the average wheat yield for 1959 was 9.7 cnt/ha for fall plow and 13.9 cnt/ha, or 43% more, for the harrowed area. As a whole, however, the yield in 1959 over 55109 ha of fall plow in the Russko-Polyanskiy rayon was 9.7 cnt/ha, while over the harrowed area of 27579 ha it was 12.1 cnt/ha, or 24% more.

We could quote many analogous examples of the high agricultural and economic effectiveness of the shallow cultivation of stubble as compared with autumn plowing. All these examples show that the increased compactness of soil in a harrowed field promotes higher wheat yields than on friable, autumn plowed fields. Increased soil compaction apparently also did not interfere in any case with the development of microbiological processes, and, consequently, with the supply of mineral nutrients necessary to growing plants. Otherwise it would have been difficult to explain the causes of the increase in the yield of wheat sown in the harrowed field.

We can find quite a number of examples in the practical work of sovkhoses and kolkhoses which characterize harrowing from a negative point of view. This is usually the case when land is harrowed which is covered by weeds, especially with perennial weeds. This occurs often when grain crops are sown repeatedly over a harrowed field for a number of consecutive years. As observations show, the lower effectiveness of harrowing as compared to autumn plowing is caused here not by increased soil compactness, but by the strong growth of weeds, which has a negative effect on the growth and development of cultivated plants.

This is indicated by the results of a comparative study of the effectiveness of plowing with and without (Mal'tsev method) a moldboard made in an old abandoned area of the SIBNII-SKHOZ. Shallow disc harrowing of the stubble for 4 years did not cause a noticeable increase in soil compactness; variations in its bulk density for this period did not exceed the limits of maximum density (1.20 g/cm³) achieved under laboratory conditions, which as we have seen, had no negative effect on the intensity of the biological process. Only the soil in the lowermost layer of the field (15-20 cm) had a density close to this maximum.

Nevertheless, during this period, the area cultivated to a shallow depth became overgrown to tremendous proportions with weeds. At the time of the wheat harvest in 1959 (fourth year) there were 1218 weeds per 1 m², while there were only 276 weeds/m² in the autumn plowed area. True, the increase in weeds in both areas was due primarily to amaranth, creeping soft grass, and certain other summer weeds which did not sprout at the time of soil cultivation prior to sowing, even when it was delayed until May 21-22. Nevertheless, the weeds reflected the level of nitrogen nutrition and the yield of spring wheat. In 1956 the yield of wheat on a field harrowed for the first time was

24.9 cnt/ha and on the plowed field, 19.6 cnt/ha. In 1959 the yield in the weed-covered field after the fourth year of harrowing was 15.5 cnt/ha, that in the autumn plowed field was 24.8 cnt/ha, or 9.3 cnt/ha more than in the harrowed field.

The foregoing material is, of course, insufficient to determine a direct correlation or other mathematical relationships between the amount of weeds, the level of nitrogen nutrition, and the yield of spring wheat. But it shows rather clearly that changes in the amount of weeds influence the intensity of biological processes in the soil and, consequently, the amount of nutrients accumulated, and not variations in the compactness of the plowed layer.

The size of the article does not allow us to analyze the other aspects of the agricultural significance of soil compactness, in particular the effect of this factor on the moisture and temperature of the soil. These problems require special discussion. Here we can only note that if compaction under the arid and semi-arid conditions of Siberia has a positive effect on biological processes, it is due primarily to its improvement of the moisture and temperature of the soil.

Conclusions

1. There was no difference in the decomposition rate of organic residues, biological activity as determined by the Shtatnov method), and nitrate accumulation in leached chernozem of 2 degrees of compaction, corresponding to a bulk density of 0.9 and 1.2 g/cm³, or to the compaction of cultivated and a non-cultivated plots.

2. Increasing the compactness of the soil by shallow disc harrowing does not lower the intensity of biological processes; this explains to a certain degree, the positive effect of this method of soil cultivation as compared to autumn plowing of chernozems in the steppe and forest-steppe regions of Siberia.

3. Harrowing must be alternated with autumn plowing because of weeds; the amount of weeds increases rapidly when the soil is tilled without a moldboard, especially with disc harrows to a shallow depth.

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COMPARATIVE CHARACTERIZATION OF WATER PERMEABILITY OF SOILS OF VARYING MOISTURE CONTENTS

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As we know, the water permeability of soils depends on a number of factors: soil texture and structure, the temperature of the soil and water, soil salinity and its degree of solonchakization, etc. However, the water permeability of the same soils is greatly influenced by their moisture content.

Soil melioration investigations for planning irrigation and watering systems include the determination of water permeability at natural soil moisture content, lower than or such as would be achieved after the reclamation of these lands with irrigation. Recently certain investigators have been determining the water permeability of soils not only under natural moisture conditions, but under moisture conditions close to those designed by the project (1, 2, 4).

When conducting soil melioration investigations in the Western Caspian region in 1957 the necessity arose for data for calculating rates for the basin-type irrigation of hay fields and pastures, as well as certain forage crops. The method of calculation proposed by us (3) was based on the dynamics of the water permeability of soils close to design conditions. The creation of such conditions in the area under investigation is practically impossible in view of the lack of water. Therefore we studied the dynamics of water permeability under natural conditions and at the same time determined correction coefficients for converting the data obtained to fit soil moisture conditions designed by the project. The latter were obtained for certain most widespread soil varieties in areas selected for irrigation, represented by brown, sandy loam solonchak soils, and meadow-estuarine, fine clay loam solonchakized soil.

The projected soil moisture before irrigation in the upper 1.5 m of soil was assumed to average 75% of the ultimate field moisture capacity. Under ultimate moisture capacity in this case we understand the amount of moisture held by the soil after excess wetting and the downward drainage of gravity water. The ground water was located at a depth of 3.5-6 m. Therefore the UFM in this case corresponded to Rodes minimum moisture capacity.

Areas 1 m² with a protective zone 0.5 m wide were established in the soil studied. The test

area and the protective zone were irrigated to excess to wet the upper 1.5 m of the soils (5000-6000 m³/ha). After the water had been absorbed the soil surface was mulched and the ultimate field moisture capacity was determined in the protective zone 3-5 days later. Then the mulch was removed and observations were made on the dynamics of soil moisture. This was done by taking soil samples from the protective zone with the Rozanov sampler 6 times. Soil samples were taken every 2 days, and when the moisture content neared 75% of UFM, samples were taken every day. A soil moisture of 75% of UFM was defined as the average weighed value for the upper 1.5 m of soil.

When a soil moisture of 75% of the ultimate field moisture capacity in the calculated layer was reached the dynamics of water permeability was determined again in the main area after soil moisture had reached 75% of the UFM (ultimate field moisture capacity) in the upper 1.5 m. Certain data obtained as a result of these determinations are presented in Table 1.

Conclusions

1. The water permeability of soils decreases considerably as their moisture content is increased to 75% of the UFM as compared to the water permeability of these soils under natural moisture conditions (by 40%-50%, on the average).

2. The dynamics of the water permeability of soils having a natural moisture content of 36%-42% of ultimate field moisture capacity and that of soils artificially wetted to a moisture content of 75% of the UFM are the same, but their water permeability differs greatly, even 7-8 hr after the beginning of wetting. In our opinion the latter is attributable to the fact that considerable time is spent on the swelling of colloids and the saturation of fine capillaries during the wetting of soils of a low moisture content.

Table 1

Water permeability of soils depending on their moisture content, m/24 hr.

Time, hr.	Brown, solonetzic-solonchakized sandy loam soil			Meadow-estuarian, deeply solonchakized, coarse clay loam soil		
	Moisture content of the upper 1,5 m					
	Natural, equal to 36% of UFM (a)	Equal to 75% of UFM (b)	b:a ratio	Natural, equal to 42% of UFM (a)	Equal to 75% of UFM (b)	b:a ratio
1	2,74	1,71	0,62	1,28	0,72	0,56
2	1,80	1,12	0,62	1,29	0,73	0,56
3	1,53	0,78	0,50	1,18	0,70	0,59
4	1,35	0,67	0,49	1,21	0,65	0,54
5	1,23	0,67	0,54	1,10	0,63	0,56
6	1,18	0,66	0,56	1,15	0,63	0,55
7	1,10	0,66	0,60			

Note: Comma represents decimal point.

3. To obtain data on the water permeability of soils for design conditions we must apply to the water permeability under natural moisture conditions correction coefficients (b:a ratio) varying from 0.49-0.62, depending on soil variety and the time elapsed after the beginning of wetting. For the calculation of irrigation rates the average of this coefficient can be taken as 0.5.

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POTENTIOMETRIC TITRATION CURVES OF SOIL SUSPENSIONS IN ORGANIC SOLVENTS

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Soil acidity is the object of many investigations. This problem was studied in the past for the determination of criteria for the chemical melioration of soils. Soil acidity and its quantitative expression were considered as the basis of the theory and practice of liming for the improvement of podzolic soils.

The study of soil acidity developed in the last 10 years under the influence of the classical concepts of acids and bases. The most widespread concept was that of the dual nature of soil acidity: a) as a result of the dissociation of the acids proper or acid-like soil acidoids, and b) as a result of secondary processes caused by the hydrolysis of salt-like compounds, primarily of an ampholytic nature. The basic role in this relationship is the aluminum. The use of organic solvents for titrating soil suspensions and extracts from the soil eliminates the phenomena caused by hydrolysis and other secondary processes and thus permits us to separate these 2 types of acidity.

Since organic solvents are used for the first time in the study of soil acidity, we must first of all determine the qualitative aspect of this problem, i. e., whether a soil suspension in an organic solvent is acid enough and whether this acidity can be titrated. If hydrogen takes part in the formation of soil acidity, it will be possible to measure the activity of the hydrogen ion in the solution and to titrate free acidity and the mobile hydrogen of the colloidal soil complex. Considering that soil acidity is due to weakly acid soil compounds, we used dimethylformamide ($\text{HCON}(\text{CH}_3)_2$) as the basic solvent for its qualitative characterization.

We investigated special soils of various genetic groups:

1. Thick chernozem from the Khar'kov State Breeding station (the sample was taken from a depth of 0-20 cm).
2. Moderately podzolic sod soil from the Kiev Oblast' (0-24 cm).
3. Slightly podzolic, gleyed, sandy loam sod soil (sown meadow) on fine clay loam from the Kalinigrad Oblast' (10-20 cm).
4. Cultivated, residual podzolic, silty clay

loam on fine clay loam from the Kirov Oblast' (0-10, 10-20, 25-30, and 40-45 cm).¹

The characteristics of the soils investigated are presented in Table 1. The pH of the water suspension of soil was determined by a glass-electrode after the soil was kept in the water for 24 hrs to achieve relative equilibrium. The dilution during all pH measurements was the same (a soil to solvent ratio of 1:5).

Exchangeable acidity was determined, as usual, by titration of the filtrate with a NaOH solution after the soil was treated with 1 N KCl. Hydrolytic acidity was determined by the Kappen method. Mobile aluminum was determined by the Sokolov method. An attempt at determining mobile aluminum by the Chernov and Nekrasov method failed.

The soil samples under study were ground, passed through a sieve with openings 1 mm in diameter, and dried at a temperature of 105°C. Before determining acidity and before titration, the absolutely dry soil sample was shaken with water or dimethylformamide and left for 24 hrs to reach relative equilibrium. A blank test was made during titration in dimethylformamide. The dimethylformamide used by us was qualified as "pure" and met requirements No. 1193-55 of the School of Technology.

The soil suspension was titrated potentiometrically with a glass-electrode in a circuit with a saturated calomel electrode:

Ag, AgCl Aqueous solution of Weibel	Glass Soil saturated pen- KCl sion	Hg ₂ Cl ₂ , Hg.
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The glass-electrode was filled with the aqueous solution of Weibel, both during titration in water and titration in dimethylformamide.

We used spherical glass electrodes from ordinary sodium electrode glass and from

¹The soil samples were kindly given us for analysis by the V. V. Dokuchayev Soil Museum of Leningrad.

Table 1

Titration acidity and composition of adsorbed bases in the soils studied, meq/100g of absolutely dry soil

Soil	Depth, cm	Hygroscopic water, %	pH of water suspension	Exchangeable acidity	Hydrolytic acidity	Mobile Al	Absorbed bases				Adsorption Capacity
							Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	
Chernozem from the Khar'-kov State Breeding Station	0-20	1,053	6,9	0,06	1,63	Trace	40,7	6,8	1,1	0,7	48,9
Slightly podzolic, gleyed sandy loam sod on fine clay loam, Kaliningrad Oblast'	10-20	1,016	6,9	0,06	1,52	"	15,4	2,1	0,7	0,2	18,2
Moderately podzolic sod soil, Kiev Oblast'	0-24	1,037	4,0	0,74	7,05	4,95	14,1	4,0	1,2	2,0	26,1
Cultivated, residual podzolic, silty clay loam on fine clay loam, Kirov Oblast'	0-10	1,019	4,6	1,51	5,35	13,09	7,7	1,5	0,6	0,4	10,9
Same	10-20	1,021	4,8	2,10	5,76	18,63	6,6	2,0	0,5	0,5	10,9
"	25-30	1,019	4,7	2,67	4,13	21,96	4,8	3,1	0,4	0,2	10,6
"	40-45	1,047	4,6	3,71	6,02	33,03	14,7	6,1	0,8	0,5	26,7

Note: Comma represents decimal point.

electrode glass No. 20,² containing lithium, lanthanum, and cesium oxides. The glass electrodes from electrode glass No. 20 are convenient for the titration of the soil water suspension in that they possess a long linear characteristic, i. e., they show alkaline errors at a high pH. When measuring in aqueous solutions, they follow the hydrogen function up to a pH of 13, while the limit for sodium electrode glass is a pH 10 solution.

In dimethylformamide we had to use electrodes of ordinary sodium electrode glass, since they gave a much more stable potential value than the electrodes of electrode glass No. 20. Before titrating in dimethylformamide we had to keep the glass-electrodes in this solution for 24 hrs at least, since in the opposite case we were not able to obtain a stable potential value. Apparently, this is associated with the slow penetration of the solvent into the swollen surface layer of the glass membrane.

Since glass-electrodes with ordinary protective casings are inconvenient for measuring soil suspensions, we used a special casing stand combination which proved to be effective under these conditions (Fig. 1). It protected the electrode well from mechanical action and at the same time the suspension did not stick to it too much. The electrode is easy to wash,

while the legs of the stand can be wiped easily with filter paper without lifting the electrode from the casing.

The soil suspension was titrated in water with 0.1 N NaOH. The soil suspension was titrated in dimethylformamide with 0.1 N NaOH in a mixture of methanol and benzene (1:4 ratio). The titration standard for this solution was succinic acid in dimethylformamide, determined potentiometrically and with an indicator (thymol blue).

Figure 2-a shows the titration curves of the water suspension of samples from the black horizons of cultivated, residual podzolic, silty clay loam soil on fine clay loam (A), and the titration curves of the suspension of the same soil in dimethylformamide (B).

As we can see, the titration curves in one and the same solvent show identical characteristics. As was to be expected, when titrating in water, the pH of the soil suspension changes continuously as more of the NaOH solution is added. These curves are characterized by a continuous change in the acidity-basicity of the soil suspension solution when alkali is added. Neither the neutralization point nor the titration of the acid components of the soil, characteristic for any acid-base titration, are reflected in these potentiometric titration curves.

A different picture is observed when titrating the suspensions of the same soils in a solution which does not contain water. The rapid transition to the horizontal section of the potentiometric

²Independent bureau for the construction of instruments and means of automation (Tbilisi).

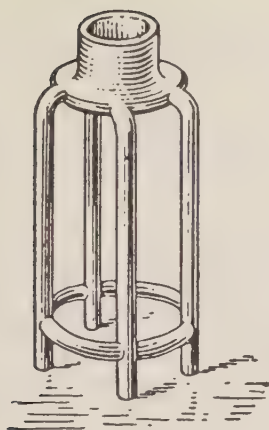


Fig. 1. - Glass casing for the spherical glass electrode.

titration curve, which occurs within the limits of 4-6 meq NaOH (as reduced to 100 g of absolutely dry soil) in every investigated sample of the foregoing soil, is an evidence of the exclusion of the process of hydrolysis during titration in an organic medium.

Consequently, the measurement of the acidity of a soil suspension in an organic solvent characterizes the actual acidity of the soil studied, while the titration of the suspension in this medium with NaOH characterizes the acidity of hydrogen ions. The NaOH solution added neutralizes the actual soil acidity, after which a further addition of the base does not cause a noticeable change in the pH of the suspension studied, and, consequently, in the e. m. f. measured.

The titration curves for the thick Khar'kov chernozem and for the slightly podzolic, gleyed sandy loam sod soil on fine clay loam from Kaliningrad (Fig. 3) are similar to those shown in Figure 2. But the dimethylformamide

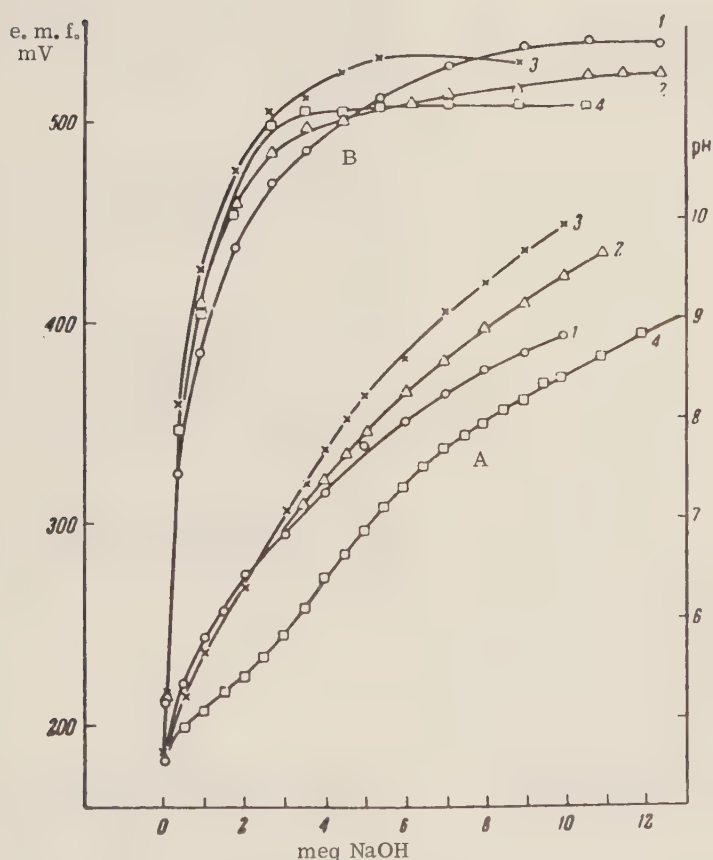


Fig. 2: - Potentiometric titration curves for the suspension of residual podzolic, silty clay loam soil.
A - in water; B - in dimethylformamide. Layers: 1 - 0-10 cm; 2 - 10-20 cm; 3 - 25-30 cm; 4 - 40-45 cm.

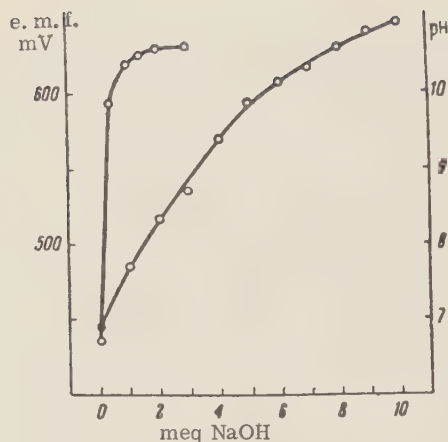


Fig. 3. - Potentiometric titration curves for chernozem and sod-podzolic soil suspensions.
A - in water; B - in dimethylformamide.

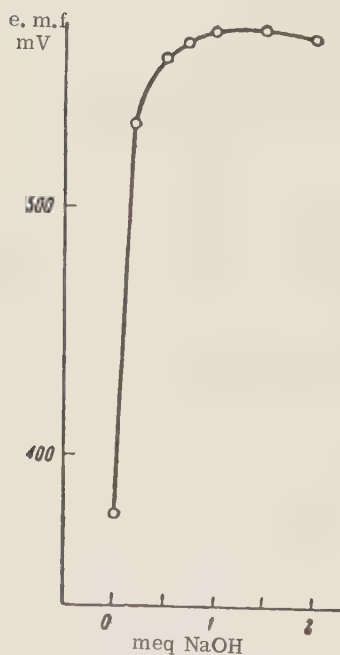


Fig. 4. - Potentiometric titration curve for the solvent (dimethylformamide)

titration curve (Fig. 3-B) fully corresponds to the curve for the control titration of the solvent (Fig. 4) when both are superimposed, the only difference being the height of the curves.

The water suspension of these soils, even though it has a pH of 6.9 (the solution is practically neutral), titrates with the NaOH

solution in the same way as sod-podzolic soils, whose suspension has an acid reaction, the only difference being that the titration curve begins at a higher pH (Fig. 3-A).

The foregoing data indicate that no hydrolysis takes place in an organic solvent (in the absence of water) and that soil acidity, created by acid soil acidoids, can be determined and titrated.

To convince ourselves that aluminum salts do not play a role in the titration of a soil suspension in dimethylformamide, we titrated $AlCl_3$ in water and in an organic solvent. In water we obtained a rather gentle curve, while $AlCl_3$ did not titrate in dimethylformamide at all. Thus, in titrating a soil suspension in dimethylformamide, we only titrate the acidity created by the acid components of the soil themselves. It is interesting to note that the Wiegner suspension effect is retained in dimethylformamide with the same sign as in water.

When titrating soil acidity in dimethylformamide, we were interested in whether or not the soil studied by us changes under the effect of the organic solvent. To find it out we treated the soil samples with dimethylformamide the same way as during titration, using the same soil to solvent ratio; we decanted the solvent after 24 hrs, dried the soil and analyzed it. The results of this analysis are presented in Table 2.

As we can see from Tables 1 and 2, the nature of the soil remained the same. Only exchangeable acidity changed somewhat after the treatment with dimethylformamide, which is only natural, since the solvent was decanted from the soil and the acid components dissolved in it were partially unavailable for analysis.

In summing up, we would like to emphasize again that the acid components of soil — acid soil acidoids, apparently also play a role in the formation of soil acidity. This soil acidity can be determined not only qualitatively, but also quantitatively, and, consequently, more objective criteria can be established to evaluate the nature of the action of lime.

In the present paper we wanted to throw light primarily on the qualitative aspect of the problem. Further studies in this direction are required to solve the quantitative aspect of this problem.

Conclusions

1. We measured soil acidity and titrated the suspensions of 7 soil samples in water and in an organic solvent (dimethylformamide).
2. We showed the different nature of titration curves in water and in an organic medium.
3. We proved that it was possible, by using

TITRATION CURVES OF SOIL SUSPENSIONS

Table 2

Titrated acidity and composition of adsorbed bases in soils treated with dimethylformamide, meq/100 g of absolutely dry soil

Soil	Depth, cm	Exchangeable acidity	Adsorbed bases			
			Total Ca ⁺⁺ + Mg ⁺⁺	Na ⁺	K ⁺	Adsorption capacity
Chernozem from the Khar'kov State Breeding Station	0—20	0,06	47,5	0,81	0,68	49,4
Slightly podzolic, gleyed, sandy loam sod soil on fine clay loam, Kaliningrad Oblast'	10—20	0,06	—	—	—	17,1
Moderately podzolic sod soil, Kiev Oblast'	0—24	0,55	17,1	0,84	1,85	26,1
Cultivated, residually podzolic, silty clay loam on fine clay loam, Kirov Oblast'	0—10	1,17	8,5	0,35	0,37	9,9
Same	10—20	1,77	8,3	0,32	0,32	10,4
"	25—30	2,23	8,1	0,38	0,36	9,4
"	40—45	3,33	19,4	0,65	0,65	24,6

Note: Comma represents decimal point.

organic medium in the study and determination of soil acidity, to eliminate the influence of secondary processes (hydrolysis) which interfere with the direct determination of the content

of acid components in soil.

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METHOD OF DETERMINING THE SWELLING OF COMPACTED SOILS

G. G. SAATCHYAN

An article by B. I. Rutkovskiy, entitled "Swelling of compacted soils" appeared in the journal "Pochvovedeniye" No. 4, 1959. As a result of his investigations the author came to the conclusion that the magnitude of relative swelling depends on the initial moisture content of the soil and not on its initial compactness. He proposes the following formula for determining relative swelling

$$\lambda = \frac{S \cdot \delta^2 \cdot h^2}{P \cdot W},$$

where S is the total particle area of the soil cm^2/g ;

δ is soil density, g/cm^3

h is the thickness of the layer, cm;

P is the additional load (external load and the weight of the swollen soil), g;

W is the moisture content of the soil.

We can easily see that the formula proposed by B. I. Rutkovskiy contradicts his conclusion that the swelling of the soil is independent of its initial density. In fact, we find the density squared in the numerator, and the weight of the soil in the first power in the denominator. Consequently, according to this formula swelling is proportional to the first power of density. If we examine the results of the experiments made by B. I. Rutkovskiy carefully, we can see the dependence of swelling on initial density. For instance, with a constant initial moisture content of the soil of 3.5% it proves that at $\delta = 1.53 \text{ g}/\text{cm}^3$ swelling is 5%, at $\delta = 1.64 \text{ g}/\text{cm}^3$ it is 7%, at $\delta = 1.73 \text{ g}/\text{cm}^3$ it is 8%, and at $\delta = 1.84 \text{ g}/\text{cm}^3$ it is 9%. Thus, the conclusion of B. I. Rutkovskiy about the lack of dependence of swelling on initial density is erroneous and is not substantiated by his experiments. Thus, for instance, if the moisture content of the soil is zero, then according to the formula, swelling is infinite, which is absurd. Further, let us take moist soil and apply any load P to it, then, according to the formula, the soil must swell. But we know that when a sufficiently large load is applied to the soil, it does not swell, but compresses. The magnitude of this compensating load can be determined experimentally. It must be noted

that Rutkovskiy writes (on the basis of the results of his experiments) that the swelling of clay loam was zero under a load of $0.081 \text{ kg}/\text{cm}^2$. The foregoing shows the inapplicability of the formula proposed by Rutkovskiy.

From 1958-1959 the All-Union Scientific-Research Institute of Transportation Construction conducted experiments on the swelling of soils of varying initial moisture contents and initial densities, and determined the forces of swelling in its road construction laboratory. The results of the experiments showed that when the initial soil density was increased when molding the sample, swelling increased. Figure 1 shows the relationship between swelling force, i. e., the load at which swelling ceases, an initial density. The experiment was made with coarse clay loam from the Moscow region. Its rolling-out-limit was 14%, its flow-limit was 25%, and its maximum molecular moisture capacity was 10%. As we can see from the

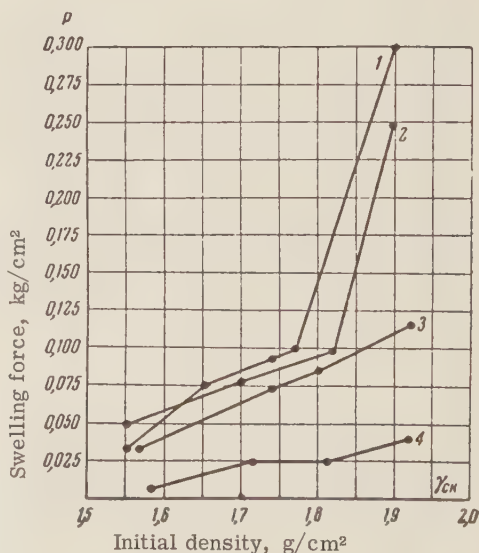


Fig. 1. - Relationship between the force of swelling and the initial density of soil. Initial moisture content: 1 - 7%; 2 - 9%; 3 - 11%; 4 - 15%.

SWELLING OF COMPACTED SOILS

graphs, an increase of density at the same moisture content on molding causes an increase in swelling forces.

Similar relationships were obtained in experiments with our soils whereby it was found that an increase in the amount of clay particles, or an increase in the plasticity of the soil causes an increase in swelling. Swelling increases especially sharply when the moisture content of the soil exceeds the maximum molecular moisture capacity. Therefore we cannot agree with the third conclusion of

Rutkovskiy that "the great majority of soils have the same swelling value at a moisture content nearing the maximum molecular moisture capacity."

Thus, experimental investigations showed that the swelling of the soil materials and soils saturated with water increases with decreasing initial moisture content and increasing initial density during molding. Under otherwise similar conditions, the swelling of various soil materials is the greater the more clay particles they contain.

CHRONICLE

THE UNITED ARAB REPUBLIC (EGYPT)

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In accordance with the existing agreement we were detailed by the Academy of Sciences of the USSR to scientific institutions in the United Arab Republic as consultants on problems of soil classification and melioration.

The soil scientists of Egypt were interested primarily in our opinion on soil genesis and classification, and problems of the agricultural reclamation and melioration of areas for which there are corresponding projects. With this objective in mind, field trips were made to a number of regions in Egypt: to the Nile delta, At-Takhrir Province, the State Farm Inchas and Faiyum oasis for the Scientific Research Center, and to the Mediterranean zone and Kharga oasis for the Desert Institute.

As a result of these trips, even though they were short, we were able to collect certain materials for becoming familiar with the processes of soil formation, with the principal soils, and with the work conducted in the reclamation of desert land in the regions visited.

In Cairo we became acquainted with soil studies in Egypt and found that considerable work is being conducted by various scientific-research institutions and chairs of institutions of higher learning. The largest soil organization — the Soil Division, created in 1953 at the Ministry of Agriculture, has 6 laboratories. This Division conducts extensive work on the qualitative characterization of irrigated lands and lands to be reclaimed when the Asswan reservoir is built. At the present time there are soil maps covering 1,600,000 feddans.¹ Another large scientific-research institution was recently organized under the Ministry of Agriculture — the Laboratory for the Study of Saline Soils, which is located near Alexandria.

There is a large soil section with a chemical laboratory, headed by Dr. Hassan Hamdi, at the Scientific-Research Center. The soil section deals with problems of soil classification and genesis. In particular, it has conducted an interesting study on the effect of sprinkling on reclaimed gravelly-sandy desert soils at the Inchas State Farm, which is located several tens of kilometers to the northeast of Cairo.²

¹A feddan is equal to 0.4 ha.

²Akhmed Gamal Abd El-Sami. Use of sprinkling* for the melioration of sandy desert soils at the Inchas farm. Pochvovedeniye, No. 12, 1960.

More extensive work in the study of soils is being conducted at the Desert Institute. The soil section is also small here and is headed by Dr. Gabali. One of the major works conducted by the Institute is the study of soil melioration conditions in the region of Maryut, which is designed to be irrigated by the drainage waters of the Nile delta.

The saline soils of the Nile delta and the dynamics of the salinization of soils and ground waters are being studied at the University of Alexandria under the supervision of Dr. Gabali. The colloidal-chemical and mineralogical composition of soils and problems of agricultural chemistry are being studied at the University of Ainsan under the guidance of Dr. Hassan Hamdi. The problems of the genesis and properties of soils, irrigation and drainage, and plant nutrition are being studied at Cairo University (Dr. Zein el Abidin and Dr. N. Yu. Shavarbi). The soils studied from these points of view included the soils of Siwa and Fayum oases and those of the western part of the Nile delta. Considerable work has been conducted in the study of Nile clay, the solodized and solonetzic soils of the Nile delta, etc.

However, the scientific-research work is still poorly coordinated as a result of the lack of a central soil science institution. There is a deficiency of qualified personnel in certain branches of soil science. The influence of American and western soil science schools is felt in scientific investigations and the methods used; the ideas of Soviet soil science are not well known. To introduce the latter, it would be a good idea to translate the major works of our scientists into English.

Let us discuss briefly the results of our field observations.

The major role in the economy of Egypt is played by the Nile valley and the Nile delta, where almost all the 6 million feddans of cultivated land are concentrated. As a result of many centuries of irrigated agriculture, unusual soils developed here. They are considered as "alluvial" or "alluvial-meadow" soils in the scientific literature and by a wide circle of agronomists. However, a number of peculiarities inherent to the present Nile soils (increased humus content, good structure, high cultivation, etc.) allow us to conclude that they developed not

only as a result of the influence of natural factors, but also under the centuries-old influence of human activity. Consequently, they cannot be likened to ordinary alluvial-meadow soils from the point of view of genetic soil science and we propose that these soils be distinguished as a special group under the name "anciently irrigated alluvial-meadow soils"

It is only natural that processes of soil salinization are developed in the Nile valley and, especially, its delta, which must be controlled.

A factor which interferes with the melioration of saline soils, especially at the periphery of the delta, is the backwater of the Mediterranean; therefore the drainage waters must be diverted mechanically.

Experiments on the reclamation of desert lands on ancient Nile terraces deserve attention. The use of modern machines, new methods of irrigation (sprinkling, light pipelines, reinforced irrigation networks, etc.), and special agricultural practices make it possible to create fertile soil rapidly from practically infertile sandy and gravelly-sandy desert soils with limited expenditures of irrigation waters. We became acquainted with these experiments in the At-Takhrir Province and at the Inchas State Farm.

New land is being reclaimed under more difficult conditions and, as of now, with less positive results in the southwestern part of Karun Lake in the Fayum oasis. Here, at the Kuta State Farm, we became acquainted with production experiments organized with the help and consultation of American specialists. Primitive saline and gypsum desert soils (clay loam and clay) on lacustrine-alluvial deposits are being reclaimed. There are also areas with shallow desert soils on calcareous parent material lying close to the surface. The major difficulties in reclamation are: the considerable salinity of soils, the large volume of leveling (up to 500 m³ per feddan), and the great deficiency of organic fertilizers for initial cultivation. Our attention was drawn to the absence of a soil map. Therefore we were not surprised that the leveling of certain areas had to be stopped because solid calcareous rock was found close to the surface.

Two trips to the Mediterranean zone gave us the opportunity to become acquainted with its natural and agricultural conditions. This zone is one of the few regions in Egypt where dry and irrigated farming are practiced. Barley, olives, and ginger are grown here as dry land crops. Because of limited atmospheric precipitation (150-200 mm a year), crop yields are small, especially that of barley, and therefore various measures are taken to retain and utilize surface runoff waters. Such land areas are selected for growing olives and ginger where additional wetting is to be expected from the side or from the condensation of water vapor, for which the conditions here are favorable. But such lands are comparatively few, even though apparently not all of them have been found yet.

An even smaller area is occupied by irrigated

agriculture using ground waters of various degrees of mineralization which are found at depths from 6-20 m. The ground water is delivered to the surface by windmills. However, the supply of fresh ground water is limited, and, as a rule, is exhausted rapidly, usually by autumn. Such comparatively small areas under irrigated agriculture have a greater variety of crops, the most valuable of which are olives and almonds.

It is rightly believed that the full utilization of the Mediterranean zone must be based on the development of every type of artificial irrigation. This is only possible by drawing water from the Nile, primarily the drainage waters of the delta presently being drained into the Mediterranean. A project for the irrigation of 33,000 feddans of land with drainage water in the Maryut region has been worked out precisely for the foregoing purposes. There are the Burg el Arab and Ras el Khakma experimental stations which are concerned with the development and improvement of various methods of land reclamation (irrigation, water and wind erosion control, etc.).

Among the unsolved soil problems is one of classification status of Egyptian soils, which are conditionally related to sierozems. Recently, certain Egyptian investigators, following in the footsteps of American soil scientists, have been distinguishing various soil series. The problem of melioration systems has not been sufficiently worked out either, since practice ran into the problem of secondary salinization and solonetzization which occur in irrigated areas. It is only natural that Egyptian soil scientists expressed the desire to hear our views on the foregoing problems, which we presented to them in written form. The nature of these is briefly this. The Mediterranean belt of Egypt is a special bioclimatic zone with unusual soils having, under automorphous conditions of development, a monotypical profile with a number of characteristic features (low humus content, high carbonate content, signs of salinization, etc.). These soils differ in their structure from Central Asiatic sierozems by the poor development of their humus profile, by the considerably more pronounced carbonate concretions, and by their light cinnamon-brown color. We have the impression that the soils of the Mediterranean zone occupy an intermediate position between sierozems and gray cinnamon-brown soils, being closer to the first in the general vagueness of the soil profile. Because of the great differences from Central Asiatic sierozem these soils deserve to be distinguished as a special subgroup of sierozems under the conditional name "subtropical sierozem." To what group or subgroup these soils belong can be decided only after we analyze the material collected.

Soil of the hydromorphous series—various solonchaks and meadow soils, are also widespread in the Mediterranean zone. In places there are soils with a thick cultivated layer, which is an evidence of the ancient agriculture in this part of Egypt.

Soil moisture condensation, which is especially pronounced in coastal sand dunes, is characteristic of the Mediterranean zone. There is even

an experimental installation at the experiment station in Ras el Khakma for collecting condensed soil moisture. The ancient Roman waterworks in the form of a series of deep wells, which have survived to our day, were also based on the utilization of the reserves of condensed moisture in sand dunes. Special installations ("dikes") are found in the Mediterranean zone for the retention of surface runoff and supplementary soil wetting. There are also interesting groups of small artificial hills ("korum"), 2-3 m high, which were built for collecting and routing rain water into the surrounding relief depressions and for increasing the moisture contents for dry-land crops (winter barley).

We must say something about the official project of utilizing the drainage waters of the Nile for land irrigation in the Maryut region. However, our calculations showed that it would be better to use the drainage waters diluted with the water of the Nile to a mineralization of not more than 1 g/liter. This would permit irrigation of twice as much land in those areas of the Mediterranean zone where soil melioration conditions are more favorable than in the Maryut region with lesser expenditures.

Of great interest to us was the process of soil formation in the deserts of Egypt. In general, 3 main types of zonal landscapes can be distinguished among the deserts of Egypt. The first includes the deserts of northern Egypt, which replace the Mediterranean desert-steppe zone with the soils characterized by us earlier. These deserts show obvious features of desert soil formation in spite of the insignificant amount of precipitation (30-70 mm). The soils developed here resemble in their structure the "plateau desert sierozems" of Central Asia.

The foregoing desert soils disappear approximately in the region of Cairo, especially to the south of it (in the direction of Fayum oasis). Here the processes of soil formation are almost absent and surface formations can be distinguished under the name "desert gypsum crusts." "Lime-gypsum crusts" on marly rock are found in the Fayum oasis region. Negative relief elements ("wadi") in such deserts serve as foci of the accumulation of water-soluble salts, which crop up at the surface.

Even more unusual are the deserts of southern Egypt. We became acquainted with them on our trip from Asyut (on the Nile) to Kharga oasis and in the oasis itself. The almost complete lack of precipitation here, the high temperature, and the insignificant relative humidity make conditions extremely difficult for soil formation. These, we may say, are abiotic deserts, free of vegetation and animals. However, the upper layers of rocks loosen, crack, change in color, and a semblance of structural units sometimes develops under the influence of various factors (primarily of a thermal nature). A change also occurs in chemical composition, primarily of an oxidizing nature, which is accompanied by the formation of new substances (gypsum, iron hydroxides, etc.). Salt movements, leading to the accumulation of salts in the surface layers of weathering rocks and along their fissures, deserve special attention. There are numerous cases of the

formation of unusual "sand solonchaks." The hydration of gypsum is also very common. Accumulations of gypsum are often found at the surface of weathering rocks and along their fissures, as well as at the surface of monadnocks. The formation of a solid, silicified crust at the surface of weathering limestone, and the formation, under certain conditions, of reddish-brown eluvium with carbonate concretions from this limestone must also be mentioned. The eluvium of such limestones appears generally in the form of a white, light, airy friable mass of calcium carbonate.

At the present time it is still difficult to judge the genetic nature of the foregoing phenomena. The causes for the formation of salt accumulations under such extremely arid conditions are not clear. Apparently, we must relate such formations to "desert weathering crusts," according to Academician B. B. Polynov, and distinguish non-saline (for instance the weathering crust of the Nubian sandstones), solonchakized, gypsum, calcareous, etc., formations among them.

Large depressions in these deserts (Kharga, Dakhla oases, etc.) are very rich in high-pressure artesian waters of a high quality, which have been used since ancient times for artificial irrigation. Irrigated oases were created on the basis of these waters, and are being expanded more and more as more artesian wells are built. It is understandable that artificial irrigation leads to the necessity of creating artificial soils, since there are no natural soils here. Profiles made in the anciently irrigated areas of the Kharga oasis showed that fertile, deeply cultivated soils developed in them as a result of prolonged irrigation. They formed from the gradual reworking of desert weathering crusts (primarily of not fine texture) as a result of the addition of earthy fertilizers and, naturally, of the action of cultivated plants and soil fauna. Inclusions of pieces of coal, earthenware fragments, etc. are an evidence of the artificial origin of these soils. Usually, there are no visible signs of salinization because of no fine textured crusts and the selection of relief elevations for irrigation. The latter ensure the discharge of excess irrigation water and salts into neighboring depressions, which became bad solonchaks.

At present, there is also a tendency to create artificial soils—with the help of machines and desalinization drainage, large-scale leveling, mineral fertilizers, etc. For instance, there is a special organization for this purpose at the Kharga oasis which is concerned with soil melioration investigations, the construction of artesian wells, and the conduct of large-scale work for the preparation of the land for reclamation. We made certain suggestions relating to the improvement of the meliorative conditions of the land in the Kharga oasis and the conduct of soil melioration investigations.

The sand formations in the Kharga oasis in the Lybian desert are unusual. Not only sand deposits, but also clay deposits, including clays rich in salts and solid clay "crusts" cover the surface of gravelly-pebbly-sandy plains and miniature barchans developing on them in the form of rolled grains ("pseudogravel"). We

could distinguish the following sand formations in the part of the oasis visited by us: 1) single barkhans, 2) chains (or groups) of barkhans, 3) hillocky-hilly sands, and 4) pebbly-gravelly sand plains.

Single large barkhans and chains of barkhans, 10-12 m high and sometimes more, move forward. In places, separate groups of barkhan chains considerably exceed single barkhans in height. Hillocky-hilly sands form primarily near various types of obstructions (natural shrubs, trees planted for the protection of the fields, canals, etc.) and do not exceed 2-3 m in height.

Pebbly-gravelly-sandy plains occupy a considerable area among the other landscapes of the Kharga oasis. They are more or less flat surfaces, usually covered with drift sand of various thickness, reaching 0.4-0.6 m and more in places. Solid rock, primarily limestone or sticky impermeable and also slightly permeable clay deposits, apparently of ancient lacustrine origin, often underly the sand layer. Chains of miniature barkhans frequently form at the surface of these plains. The color of the eolian deposits varies from pale yellow-yellow to yellow-brown; brown and gray predominate in places. The deposits are considerably less

sorted than the sand forming the barkhans and sometimes they have a pronounced stratified structure with salt concretions and a thin salt crust. These are isolated sandy solonchaks. The surface of eolian sand deposits is covered with a thin layer of gravel, which acts as a type of mulch, protecting to a certain degree the underlying sand deposits from deflation.

The sand plains in the oasis belong to the category of better lands, fully suitable for agricultural use by irrigation, especially in those places where the drift sand is underlain by water-permeable limestone. However, wind erosion control measures must be taken in reclaiming these lands.

In summary we can say that our 3-month stay in Egypt was very useful. We established good business relations, especially with: Professor Khamdi and Dr. Gamal (Scientific-Research Center), Dr. Draz and Dr. Atef (Desert Institute), and Master Mohammed Abd el Rakhman Gali (Ministry of Agriculture). We invariably felt the good will toward us on the part of many specialists, young scientists, technical personnel, and ordinary citizens.

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IN COMMEMORATION OF THE 75TH BIRTHDAY OF O.K. KEDROV-ZIKHMAN

M. V. KATALYMOV

Professor Oskar Karlovich Kedrov-Zikhman, active member of the All-Union Lenin Academy of Agriculture, active member of the Academy of Sciences of the Belorussian SSSR, and doctor of agricultural and chemical sciences, celebrated his 75th birthday and 50 years of his scientific, teaching, and social activity at the end of December, 1960.

The name of Kedrov-Zikhman is widely known not only among scientific workers in the field of agricultural chemistry and related disciplines, but also among agronomists and kolkhoz workers.

O. K. Kedrov-Zikhman was born in 1885 in the family of a Latvian peasant. After graduating from the gymnasium, Oskar Karlovich entered Kiev University from which he graduated in 1913. Immediately thereafter he began to work as a probationer at the Department of Agriculture under the supervision of A. I. Dushechkin, then as a chemist at the laboratory of the Mironov experiment station and as an assistant at the Kiev regional experiment station. In 1920 Oskar Karlovich joined the Red Army as a volunteer. Following the demobilization he worked at the Uman' agricultural department, and at the end of the civil war Oskar was a teacher and then a professor and head of the chair of agricultural chemistry and soil science at the Goretz Agricultural Institute (BSSR). At the same time he headed the agricultural chemistry department of the Goretz agricultural experiment station. In 1930 Oskar Karlovich was invited to the Timiryazev Agricultural Academy in Moscow in the capacity of professor of agricultural chemistry, where he worked until 1942. At the same time he conducted scientific-research work at the Institute of the Northern Grain Economy, the Scientific Institute of Fertilizers (NIU), and the All-Union Flax Institute. From the moment the All-Union Institute of Fertilizers and Agricultural Soil Science (VIUA) was organized in 1931, and to this day, Oskar Karlovich works as the director of the laboratory of soil liming and is one of the leading members of this Institute. His work is devoted primarily to the liming of soils. He and his collaborators developed a number of methods for increasing the effectiveness of soil liming, established conditions for the most expedient combination of liming and the use of organic and mineral fertilizers, showed ways of using small amounts

of lime, and defined the biological characteristics of the major agricultural crops in relation to soil acidity, to the adsorption of cations in the soil, to the chemical composition of materials used for liming, to amounts and methods of using lime, etc. The work of Oskar Karlovich showed that liming is a means for drastically improving sod-podzolic and other acid soils and increasing their fertility. Oskar Karlovich devoted great attention to the study of the composition of adsorbed cations in the soil and its significance to the growth and development of agricultural crops. This work represented the continuation and further development of the classical investigations of K. K. Gedroyts. The work of Oskar Karlovich shows that the presence of magnesium in lime materials sometimes affects an increase in the effectiveness of liming. His study of the form of lime materials permitted him to evaluate in detail, from an agricultural chemical standpoint, various lime samples and to considerably widen their assortment. He showed the expediency of using lake lime, peat-tuff, and various industrial lime wastes (dolomitic dust, various calcareous slags, etc.) for liming. A large number of works by Oskar Karlovich is devoted to the study of the role of micro-elements in plant nutrition and to the study of the effectiveness of micro-fertilizers. He devoted most of his attention to the study of the role of boron, molybdenum, and cobalt. The work of Oskar Karlovich confirmed the great importance of boron fertilizers when used together with lime and showed the positive effect of boron as well as magnesium not only on crop yield, but also on the quality of seeds.

The investigations of O. K. Kedrov-Zikhman and of his students showed that the liming of acid soils improves the molybdenum nutrition of plants and reduces their requirement for molybdenum fertilizers. Under the immediate supervision of Oskar Karlovich his collaborators conducted pot and field experiments which, for the first time, showed the positive effect of cobalt on the yield of a number of agricultural crops when grown on limed sod-podzolic as well as peat-bog soils. The use of the radioactive isotope Co^{60} made it possible to study the effect of lime on the uptake of cobalt by plants, its speed of movement, and the localization of this element in various plant organs.

Among the work with other microelements we must also note the results of field and pot experiments which showed the positive effect of manganese fertilizers on limed sod-podzolic soils. The radioactive isotopes of calcium — Ca^{45} , cobalt — Co^{60} , and zinc — Zn^{65} were extensively used in the study of the role of calcium and microelements in plant nutrition.

A number of works by Oskar Karlovich were devoted to other essential problems of agricultural chemistry — problems of methods in agricultural chemistry investigations, the use of ground rock phosphate, peat, and green manure, etc. He published about 300 scientific works and scientific-popular articles on various problems of agricultural chemistry.

Oskar Karlovich worked extensively in the preparation of young cadres. While conducting important scientific and pedagogical work, Kedrov-Zikhman also takes active part in

social life. He has taken part in the revolutionary movement since he was a youngster. Being a member of the Communist Party since 1919, Oskar Karlovich devotes his life to the fulfillment of the tasks set by the party for the development of Soviet science and socialistic agriculture. Oskar Karlovich is respected and loved by a wide circle of scientific workers as a scientist with principles and an attentive and sensitive teacher. His great achievements in science and teaching were rewarded by the government. He was awarded the Lenin order, two orders of the Red banner, the "Znak Pocheta" order, and medals.

Let us congratulate Oskar Karlovich Kedrov-Zikhman on this memorable date in his life and wish him health, long years of happiness, and further achievements in his work for the good of our socialistic Motherland.

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